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HARMFUL AQUATIC ORGANISMS IN BALLAST WATER

Application for Final Approval of the BlueZone™ Ballast Water Management System

Submitted by the Republic of Korea

SUMMARY

<i>Executive summary:</i>	This document contains the non-confidential information related to the application for Final Approval of the BlueZone™ Ballast Water Management System in accordance with the <i>Procedure for approval of ballast water management systems that make use of Active Substances (G9)</i> , adopted by resolution MEPC.169(57) ¹
<i>Strategic direction:</i>	7.1
<i>High-level action:</i>	7.1.2
<i>Planned output:</i>	7.1.2.4
<i>Action to be taken:</i>	Paragraph 17
<i>Related documents:</i>	BWM/CONF/36; MEPC 53/24/Add.1; MEPC 57/21; MEPC 58/2/4; MEPC 59/2/13; MEPC 61/2/15; BWM.2/Circ.13/Rev.1 and BWM.2/Circ.37

Introduction

1 Regulation D-3.2 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, stipulates that ballast water management systems which make use of Active Substances to comply with the Convention shall be approved by the Organization, based on a procedure developed by the Organization.

2 The *Procedure for approval of ballast water management systems that make use of Active Substances (G9)*, adopted by resolution MEPC.169(57), defines the principal aspects to be documented by data or testing (Procedure (G9), paragraph 4.2.1) and some basic

¹ This document is over 20 pages long and, in accordance with paragraph 6.11 of the Committees' Guidelines (MSC-MEPC.1/Circ.4/Rev.2), only the first three pages will be translated into the three working languages, with the annex in English only.

principles for risk evaluation (Procedure (G9, paragraph 5.3). According to section 6 of Procedure (G9), the Organization should evaluate the information provided in the application.

3 According to BWM.2/Circ.37, proposals for approval of ballast water management systems that make use of Active Substances are to be submitted to the Marine Environment Division of the Organization, to be reviewed by the GESAMP-Ballast Water Working Group (GESAMP-BWWG). In the meantime, a document on the proposal for approval containing all the non-confidential data related to the respective ballast water management systems that make use of Active Substances needs to be submitted to MEPC.

4 Based on the definitions contained in the revised Methodology for information gathering and conduct of work of the GESAMP-BWWG (BWM.2/Circ.13/Rev.1), this document is written for approval of ballast water management systems that make use of Active Substances.

5 The Republic of Korea submitted to MEPC 65 (MEPC 65/2/5) an application for Basic Approval of the BlueZone™ Ballast Water Management System (BWMS). Following the assessment by the GESAMP-BWWG, Basic Approval was granted at MEPC 65 for the BlueZone™ BWMS (MEPC 65/22, paragraph 2.3.3).

6 The competent authority in the Republic of Korea has verified the application dossier prepared by SUNBO Industries Co. Ltd in compliance with the data requirements of Procedure (G9)).

7 Therefore, the Republic of Korea submits the non-confidential part of the applicant's dossier in the annex to this document to the Organization for evaluation according to Procedure (G9). The complete dossier will be made available to the experts of the GESAMP-BWWG with the understanding of confidential treatment.

8 Having addressed all further testing requirements for Final Approval, as stipulated in Procedure (G9), and comments from the GESAMP-BWWG on the Basic Approval, the Republic of Korea hereby submits to the Organization, in the annex to this document, the non-confidential part of the manufacturer's application dossier. The complete proposal for Final Approval including the application dossier and relevant documents will be submitted to the Marine Environment Division of the Organization to be reviewed by the GESAMP-BWWG in accordance with Procedure (G9).

Summary of non-confidential information on the BlueZone™ BWMS

9 Ozone (O₃) is defined as the Active Substance in the BlueZone™ BWMS.

10 The BlueZone™ BWMS is designed by SUNBO Industries Co. Ltd. This system consists of an ozone generation module, a mainstream ozone micro-bubble module, a neutralization module and a monitoring and control module. This system performs a two-step treatment:

- .1 disinfection step – with in situ micro-sized ozone bubbles generated by a bubble nozzle during the ballasting process. The disinfection using the ozone bubbles includes the following steps:
 - the ozone gas is injected in the form of micro-sized bubbles into the main ballasting pipe using a micro bubble nozzle;

- the ozone micro bubbles react with the bromine ions in the seawater to generate TRO during ballasting; and
- .2 neutralization step – adding sodium thiosulfate solution (hereafter thiosulfate solution) into the treated ballast water during the deballasting process to neutralize the TRO:
- the injection rate of thiosulfate solution is automatically controlled.

11 During the ballasting process, the micro-sized ozone bubbles enlarge the contact surface between the seawater and ozone gas, and have higher efficiency in killing aquatic organisms in the treated water compared to larger ozone bubbles. The ozone gas in ballast water was injected with a maximum amount of 2.3 mg/L TRO as Cl₂ (maximum dose). The TRO is automatically controlled by human machine interface (HMI) and programmable logic controller (PLC). To automatically control the maximum TRO at less than 2.3 mg/L as Cl₂, the parameters should be input to the PLC by the operator.

12 A neutralizing agent, thiosulfate solution, is injected into the deballasting pipe to neutralize the remaining TRO during the deballasting process. The injection rate of the thiosulfate solution is controlled so that discharge water TRO is below the Maximum Allowable Discharge Concentration (MADC), 0.2 mg/L TRO as Cl₂.

13 The results of biological efficacy tests show that the BlueZone™ BWMS satisfies the performance standard described in regulation D-2. The results of the chemical and aquatic ecotoxicity tests in accordance with Procedure (G9) are reported in the application dossier.

14 The predicted environmental concentrations (PEC) of disinfection by-products (DBPs) were calculated by use of the MAMPEC-BW Model 3.0 exposure model. The Predicted No Effect Concentrations (PNEC) were from the available information on acute and chronic aquatic toxicity. The environmental risk quotients (RQs) for DBPs in all samples including the treated discharge water were mostly far less than 1 even under the worst-case scenario, but a little higher than 1 for monobromacetonitrile in seawater and dibromoacetonitrile in seawater and brackish water.

15 The health risks of Relevant Chemicals posed by the BlueZone™ BWMS were assessed under various exposure scenarios. The treatment by the system has negligible adverse effects upon inhalation, dermal and/or oral exposure route. It was demonstrated that proper operation and an appropriate response to the present system assures the safe operation of ships and the safety of both the ship's crew and the general public (section 7.2).

16 In conclusion, the risk assessments show that operation of the BlueZone™ BWMS will not cause adverse effects on the aquatic organisms as well as on human health.

Action requested of the Committee

17 The Committee is invited to consider the proposal for Final Approval and decide as appropriate.

ANNEX

NON-CONFIDENTIAL INFORMATION ON THE BlueZone™ BALLAST WATER MANAGEMENT SYSTEM

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1 INTRODUCTION

SUNBO Industries Co. Ltd. and DSEC Co. Ltd. conducted land-based testing for Final Approval, carefully considering and accepting all comments and recommendations made by the GESAMP-BWWG during its twenty-fifth meeting. The GESAMP-BWWG's recommendations (in bold text) and SUNBO and DSEC's responses (in plain text) are outlined below.

The application for Basic Approval of the BlueZone™ BWMS was submitted by the Republic of Korea (MEPC 65/2/5) and was granted at MEPC 65. The comments received from the GESAMP-BWWG on the BlueZone™ BWMS Basic Approval application dossier are summarized below (MEPC 65/2/19, annex 3).

1.1 Responses to the GESAMP-BWWG's comments on the application for Basic Approval

1.1.1 (11.4.2) The Group recommends that further consideration of the process whereby the TRO sensor measures the TRO dose using the DPD method will be needed for the further development of this BWMS.

Response:

The BlueZone™ BWMS uses a TRO sensor with the DPD method, which measures the chlorine residual in water. During the land-based testing all TRO was measured with the DPD method, with the results shown in appendix XIII.

An emerging technique for TRO measurement is amperometry, which is an electrochemical technique that measures the change in current resulting from chemical reactions. In view of the reliability due to the flow and pressure sensitivity, the BlueZone™ BWMS will employ in the future online TRO sensor using amperometry with improved features such as easier calibration, self-cleaning, reagent-free and fast response (Huntly and Malkov, 2009).

1.1.2 (11.4.3) The Group recommended that the applicant ensure that the control scheme can maintain the TRO dose and MADC effectively in the full-scale BWMS at all times, and in particular to avoid unacceptable TRO levels at the beginning of discharge.

Response:

The control scheme is designed to maintain TRO at 2.3 mg/L as Cl₂ during ballasting and the remaining TRO concentration of the discharged water lower than MADC at 0.2 mg/L TRO as Cl₂ during deballasting. This is described in detail in the operation manual in appendix XII and summarized in section 4.2 of this document.

To prevent a high TRO discharge concentration at the beginning of deballasting, the neutralizer solution is injected simultaneously. During the initial two minutes of deballasting, TRO is not detected due to the sensor's measurement interval. Therefore, the injection rate of the neutralizer solution is set at 80 mL/min for neutralizing MD (2.3 mg/L TRO as Cl₂) for the first 2 minutes of deballasting. The initial injection rate (80 mL/min) is obtained by multiplying the calculated value (60 mL/min) by a safety factor (1.3).

- 1.1.3 (11.4.4) The Group recommended additional sampling for chemical analysis between day 0 and day 5 (day 1 or day 2) since the Group is of the opinion that, especially in the case of micro-bubble ozonation, the ozone gas contained in the micro-bubbles in the ballast water tank is expected to produce additional DBPs.**

Response:

Following the recommendation, additional sampling was made at day 1 for chemical analysis on three types of water as fresh, brackish and seawater. The results of chemical analysis on day 1 are shown in tables 3.3 and 3.4 and appendix III, which shows similar results to those at day 0 or day 5 except for bromate, bromoform, dibromoacetic acid (DBAA), dibromochloroacetic acid (DBCA) and monobromoacetonitrile, which often were in higher concentrations at day 1 than at day 0 or 5.

- 1.1.4 (11.4.5) The Group recommended that all risk mitigation measures to be installed and/or implemented on board are fully detailed in the operation manual to be included in the dossier for Final Approval.**

Response:

All risk mitigation measures are fully described in the operation and safety manual, appendix XII. The following are included:

- safety measures for system operation;
- definition of pictographs and signal words, action-related hazard warnings;
- personnel, local conditions, personal protective equipment, detections of gas;
- requirements for the operating personnel, protective equipment, behaviour in emergency situations, installation location;
- hazardous substance of ozone, oxygen, neutralizing agents;
- health risks and precautions for ozone, oxygen and neutralizing agents;
- structured "what if" check list for hazard identification;
- possible residual risks such as electrical, thermal hazards; and
- safety instructions such as cleaning and maintenance.

Safety of personnel and system, regular check list and alarm list of system are described in the maintenance section.

- 1.1.5 (11.4.6) The Group noted that a full report of corrosion tests will be included in any application for Final Approval and recommended that corrosion testing, in accordance with the recommendations provided in the revised Methodology, should be performed.**

Response:

The results of a full scale of corrosion tests are reported in appendix XI. Corrosion testing was carried out for a duration of six months in accordance with the recommendations provided in the section 3.6.9 of the revised Methodology for information gathering and conduct of work of the GESAMP-BWWG (BWM.2/Circ.13/Rev.1). The results of corrosion tests with an epoxy coated steel specimen show that there was no significant change in performance during the test period of corrosion resistance between the untreated and treated seawater. Also, the results for uncoated metallic specimens 316 L, titanium, copper and brass in the control (untreated) and treated seawater were similar to each other.

The immersion corrosion test for non-metals showed similar rates of corrosion between the untreated and treated seawater. Non-metals were three types of rubber specimens: NBR, EPDM, and VITON (FKM).

1.1.6 (11.4.7) The Group recognized that risk mitigation measures are required for personnel entering ballast water tanks. Considering that the tank may contain a noxious atmosphere in the headspace, the Group recommended that appropriate procedures are developed for tank entry, which may include:

- emptying of a full ballast tank and thereby replacing the atmosphere in the tank
- ventilation of a ballast tank prior to personnel entry;
- continuous ventilation during entry;
- respiratory protection; and
- skin and eye protection.

Response:

This question is partly related to 1.1.4 and procedures for entry into ballast water tanks were incorporated into the operation and safety manual, in section 4.15 for mitigating risks. The safety procedures before entering ballast tanks are as follows:

- ventilation of ballast tanks;
- atmosphere monitoring for safety;
- preparation and personal protective equipment (PPE) for entry;
- arrangement for sufficient rescue and resuscitation equipment available at the enclosed space entrance; and
- maintenance of ventilation and illumination while the enclosed space is occupied.

1.2 Brief history of the BlueZone™ BWMS

SUNBO Industries Co. Ltd., DSEC Co. Ltd. and the Korea Institute of Machinery and Material (KIMM) jointly developed the BlueZone™ Ballast Water Management System with the support of the Korean National Research and Development Program of Daedeok Innopolis.

SUNBO is one of the major companies in the Republic of Korea to fabricate and assemble structural and outfitting components for the shipbuilding industries since 1986 and has been in a leading position on the development of the BlueZone™ BWMS.

DSEC is a total ship and marine engineering company handling design, procurement, inspection and logistics since 2002.

KIMM conducted research on core technology (micro-size ozone bubble generation) in environmental machinery, with the aim of enabling the development of green technology.

The land-based test was performed from June to December 2013 for IMO Final Approval.

The land-based test facility for Final Approval and type approval of the BlueZone™ BWMS is situated on the South Sea Research Institute of KIOST (Korea Institute of Ocean Science and Technology) in Geoje, Republic of Korea.

Biological efficacy tests, aquatic eco-toxicity tests, chemical analysis for disinfection by-product identification (DBPs), risk assessments of discharge water and corrosion tests were performed and evaluated by KOMERI (Korea Marine Equipment Research Institute), NeoEnBiz Co., Lab-Frontier Co. and KTR (Korea Testing and Research Institute), respectively.

The biological efficacy test results show that the BlueZone™ BWMS satisfies the performance standard described in regulation D-2 of the Ballast Water Management Convention. The results of the chemical and acute/chronic toxicity test in accordance with the *Procedure for approval of ballast water management systems that make use of Active Substances (G9)* are reported in the application dossier.

1.3 Abbreviations used in the text

ABBREVIATIONS

ADD	Average Daily Dose
AS	Active Substance
ASTM	American Society for Testing of Materials
BA	Basic Approval
BCF	bioconcentration factor
BWMS	ballast water management system
CAS	Chemical Abstracts Service
CV	coefficient of variation
DNEL	Derived No-Effect Level
DOC	dissolved organic carbon
EC ₅₀	Effect Concentration, 50% (median effective concentration)
GLP	good laboratory practice
HMI	Human Machine Interface
ISO	International Organization for Standardization
K_{oc}	organic carbon-water partition coefficient
K_{ow}	octanol/water partitioning coefficient (also P_{ow})
K_p	sorption coefficient for ionic substances
LC ₅₀	lethal concentration, 50%
LD ₅₀	lethal dose, 50%
LOAEL	lowest observed adverse effect level
LOEL	lowest observed effect level
Log P_{ow}	logarithm of the octanol/water partition coefficient
MADC	Maximum Allowable Discharge Concentration
MAMPEC-BW	Marine antifoulant model for PEC calculation for ballast water
MB	micro bubble
MD	maximum dose
MOMB	mainstream ozone micro bubble
NOAEC	No Observed Adverse Effect Concentration
NOEC	No Effect Concentration
NOAEL	No-Observed-Adverse-Effect Level
NOEL	No-Observed-Effect Level
OECD	Organisation for Economic Co-operation and Development
PBT	Persistence, Bioaccumulation and Toxicity
PEC	Predicted Environmental Concentration
PLC	Programmable Logic Controller
PNEC	Predicted No Effect Concentration
POC	Particulate organic carbon
P_{ow}	octanol/water partition coefficient (also K_{ow})
PPE	Protective Personal Equipment
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RC	Relevant Chemical
RCR	Risk Characterization Ratio
TOC	Total Organic Carbon

TRO	total residual oxidant
US EPA	United States Environmental Protection Agency
WET	whole effluent toxicity test

2 OVERVIEW OF THE LAND-BASED TEST SCHEME ON THE BlueZone™ BWMS

2.1 Observance of the regulation

The legal provision for this application is regulation D-3.2 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, which stipulates that ballast water management systems that make use of Active Substances shall be approved by the Organization. During its 53rd session, the Marine Environment Protection Committee (MEPC) adopted the *Procedure for approval of Ballast Water Management Systems that make use of Active Substances* (G9) through resolution MEPC.126(53). The revised Procedure (G9) was adopted by resolution MEPC.169(57). This application and the comprehensive test programme that has been conducted by SUNBO Industries Co. Ltd. to support it are in full compliance with Procedure (G9).

2.2 Principles of acceptability of BWMS that make use of Active Substances

In accordance with Procedure (G9) and as presented in this document, SUNBO Industries Co. Ltd. has sought to meet the principles of acceptability by undertaking comprehensive toxicity testing of ballast water treated with the BlueZone™ BWMS in system testing, in order to determine the level of risks of the disinfection by-products to the receiving environment or human health.

2.3 Submission of an application for Final Approval

This application is for Final Approval. The information in this dossier includes:

- results of the comprehensive Procedure (G9) toxicity testing and chemical analysis;
- results of the Guidelines (G8) efficacy testing;
- Quality Assurance Project Plan (QAPP); and
- technical specifications of the optimized BlueZone™ BWMS.

2.4 Confidentiality and data protection

All information contained in this application and the supporting documents is to be considered as confidential, except that included in the non-confidential summary document. SUNBO Industries Co. Ltd. accepts that all items listed in section 2.4 of the Methodology (BWM.2/Circ.13/Rev.1) will not be regarded as confidential once the system and Active Substance are approved.

2.5 Test methods

The undertaking of comprehensive tests for efficacy and toxicity of the BlueZone™ BWMS consists of four steps:

- .1 sampling;
- .2 determination of water quality parameters and efficacy testing of the samples (Guidelines (G8) testing) – five trials for seawater and brackish water, and one trial for fresh water;

- .3 chemical analysis of the samples (Procedure (G9) testing) - one trial for each type of test water; and
- .4 Whole Effluent Toxicity (WET) testing of the samples (Procedure (G9) testing) – one trial for each type of test water made at the same time with chemical analysis.

All test methods were carried out in compliance with the requirements of the Guidelines (G8) and Procedure (G9). All of the tests were supervised by staff of KIOST, which is a governing body of the overall quality of the tests.

2.5.1 Land-based test information

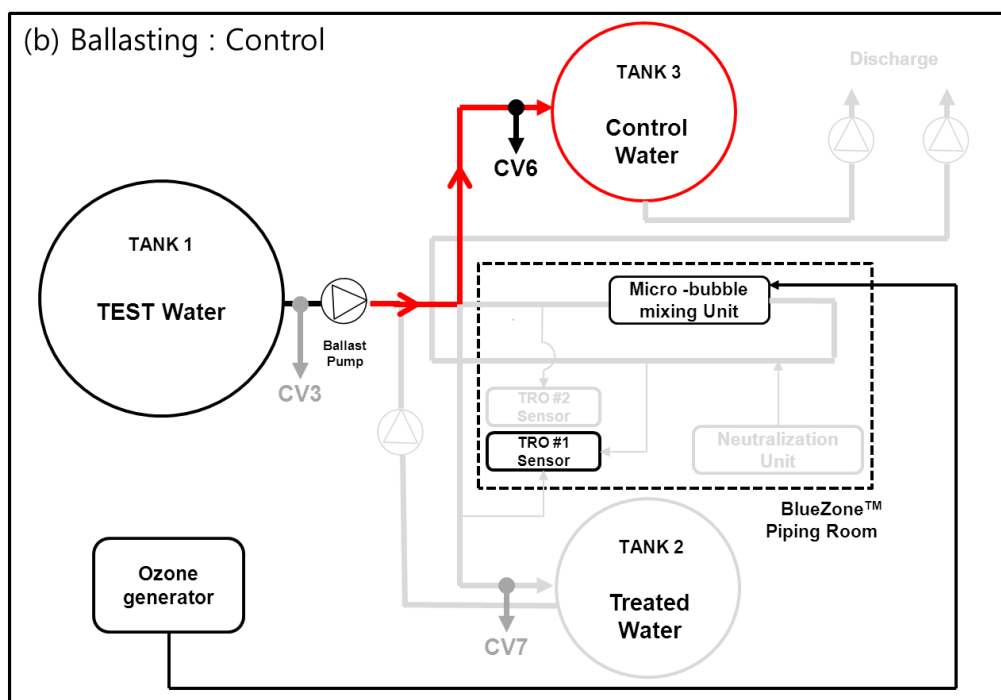
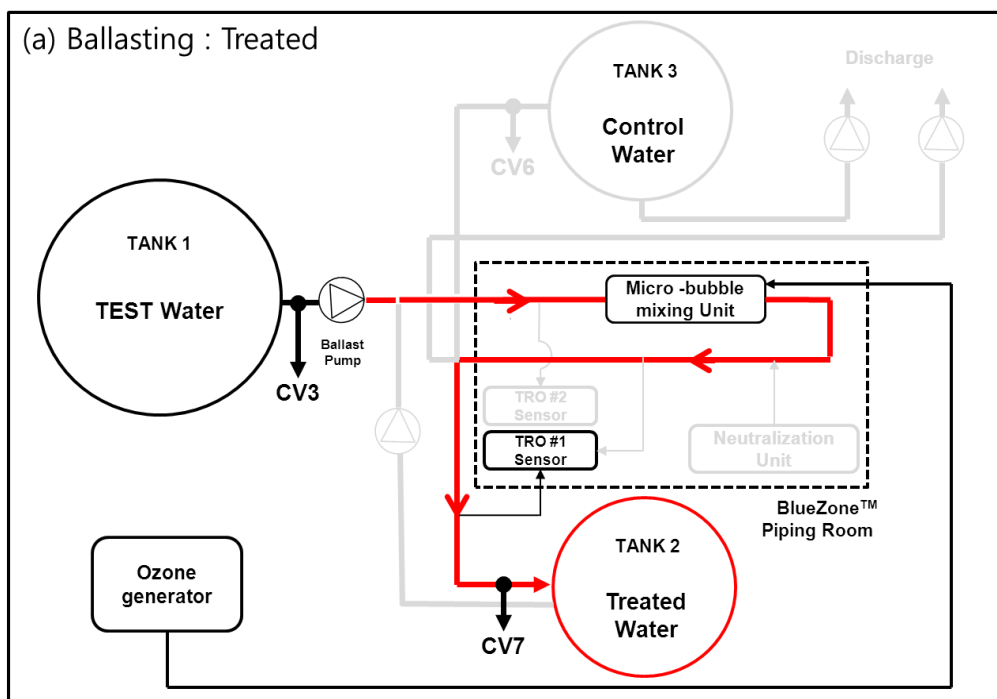
Three types of water (seawater, brackish water and fresh water) were used for the purposes. An overview of the land-based testing scheme is presented in table 2.1.

Table 2.1: Information on the land-based tests

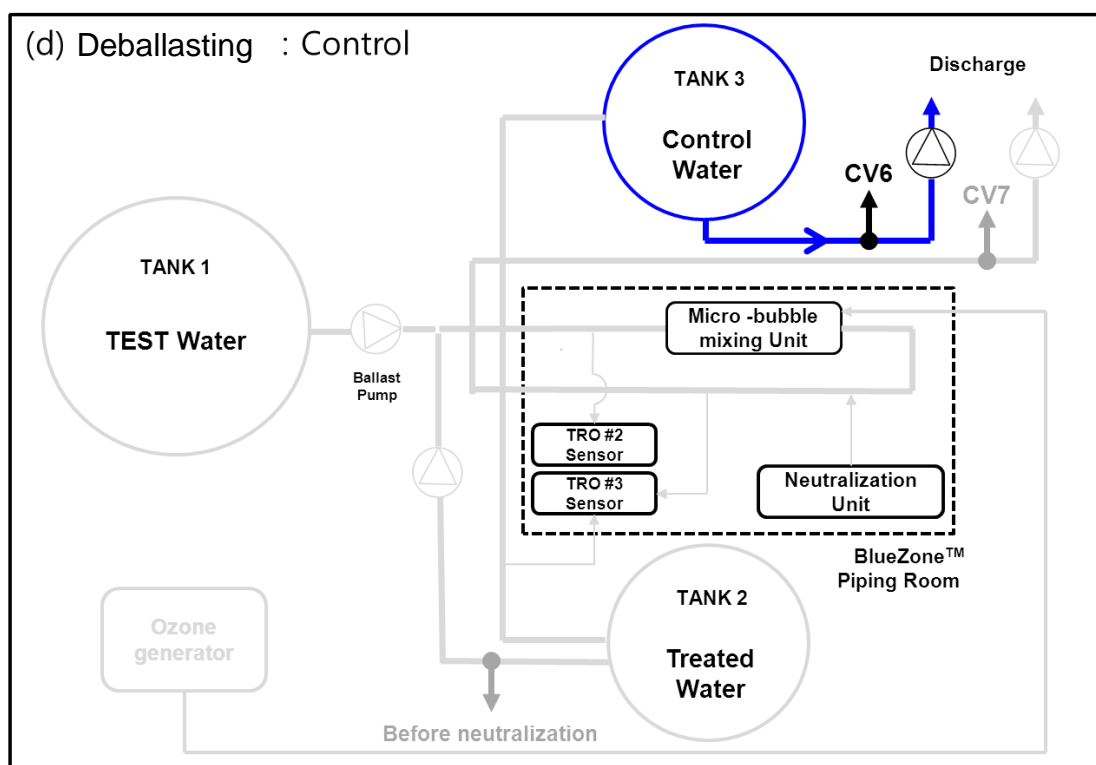
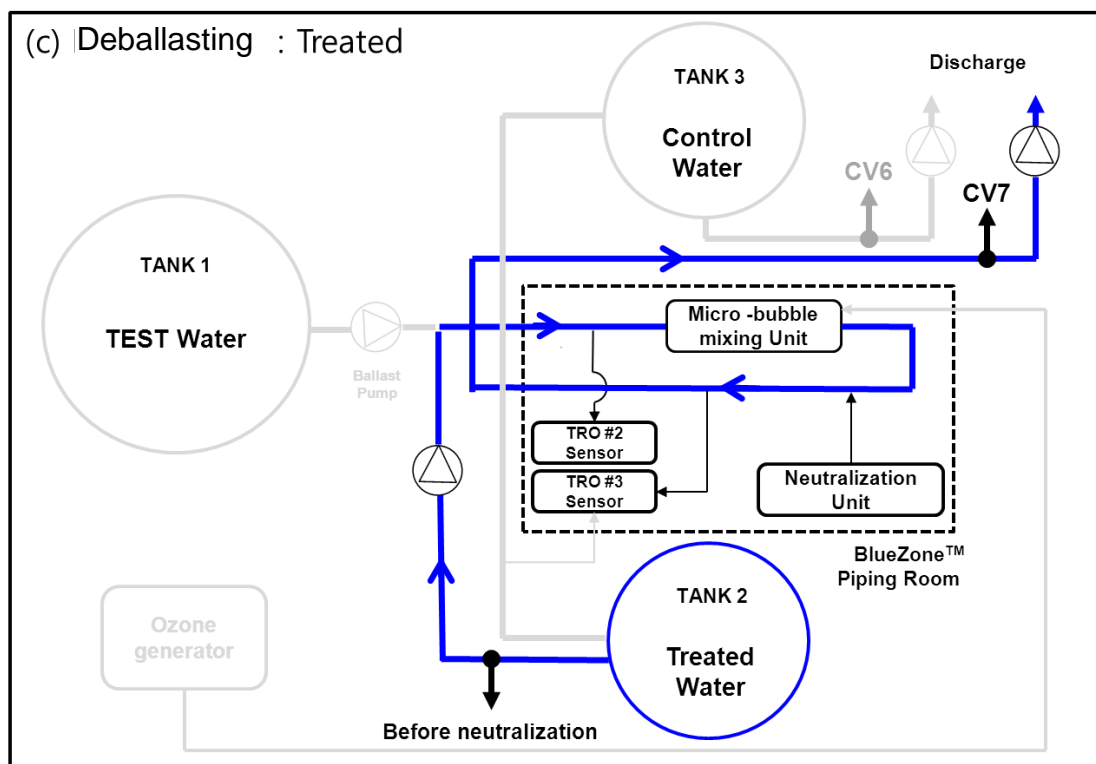
	Seawater	Brackish water	Fresh water
Test site	41 Jangmok1-gil Jang-Mok Myon Geoje 656-834, Republic of Korea		
Number of trials	5 trials	5 trials	1 trial
Salinity (PSU)	33	21	< 3
Ballast flow rate (m ³ /h)	250 ± 5		
Tank volume (m ³)	Treated: 250; Control: 250		
Test water tank volume (m ³)	500		
Maximum TRO concentration in ballasting line	2.3 mg/L TRO as Cl ₂		
Neutralizer	Sodium thiosulfate solution (Na ₂ S ₂ O ₃ , 30% w/v)		

2.5.2 Sampling

The flow diagram of the test facility is shown in figure 2.1. The facility has three tanks, test water is being pumped out at 500 m³/h into the two tanks with half of water treated and the other not treated. Both control and treated water are discharged at day 5, sent to a reservoir. Sampling points are CV3, CV6 and CV7 in figure 2.1. The grab samples for performance analysis (biological efficacy test) were collected in triplicates at the beginning, middle and end of ballasting and deballasting respectively. Samples for the chemical analysis and aquatic ecotoxicity test were collected once in the middle of performance analysis sampling. Samples for Relevant Chemical analysis were directly collected from treated water (TANK 2) at day 0, day 1 and day 5 before neutralization.



(a) Water flow during ballasting in the land-based test



(b) Water flow during deballasting in the land-based tests

Figure 2.1: Test water flow diagram and sampling points

Table 2.2: Sampling information for the land-based tests of the BlueZone™ BWMS

Sampling for		Sample ID (sampling location)		On-site measurement	Off-site measurement	Salinity		
		Treated water	Control water					
Aquatic toxicity test	Day 0: ballasting	Only after neutralization S-Treated (D0) B-Treated (D0) F-Treated (D0) (CV7)	S-Control (D0) B-Control (D0) F-Control (D0) (CV6)	-	- Microalgae - Rotifer - Fish	- 33 PSU - 21 PSU - < 3 PSU		
	Day 1: Deballasting	Only after neutralization S-Treated (D1) B-Treated (D1) F-Treated (D1) (CV7)	S-Control (D1) B-Control (D1) F-Control (D1) (CV6)					
	Day 5: Deballasting	Only after neutralization S-Treated(D5) B-Treated(D5) F-Treated (D5) (CV7)	S-Control (D5) B-Control (D5) F-Control (D5) (CV6)					
Chemical analysis	Test water	Test water (CV3)		- TRO Conc.	- Relevant Chemicals		- 33 PSU - 21 PSU - < 3 PSU	
	Day 0: ballasting	Before and after neutralization of S-Treated(D0) B-Treated(D0) F-Treated (D0) (CV7)	S-Control (D0) B-Control (D0) F-Control (D0) (CV6)					
	Day 1: Deballasting	Before and after neutralization of S-Treated(D1) B-Treated(D1) F-Treated (D1) (CV7)	S-Control (D1) B-Control (D1) F-Control (D1) (CV6)					
	Day 5: Deballasting	Before and after neutralization of S-Treated(D5) B-Treated(D5) F-Treated (D5) (CV7)	S-Control (D5) B-Control (D5) F-Control (D5) (CV6)					
Biological efficacy test	Test water	Test water (CV3)		- Organisms: ≥ 50 µm, ≥ 10-50 µm - Temp. - Salinity - DO - pH - NTU	- Bacteria - DOC - TOC - TSS			- 33 PSU - 21 PSU - < 3 PSU
	Day 0: ballasting	S-Treated (D0) B-Treated (D0) F-Treated (D0) (CV7)	S-Control (D0) B-Control (D0) F-Control (D0) (CV6)					
	Day 1: Deballasting	S-Treated (D1) B-Treated (D1) F-Treated (D1) (CV7)	S-Control (D1) B-Control (D1) F-Control (D1) (CV6)					
	Day 5: deballasting	S-Treated (D5) B-Treated (D5) F-Treated (D5) (CV7)	S-Control (D5) B-Control (D5) F-Control (D5) (CV6)					

A detailed description for each sample in table 2.2 and figure 2.1 is as follows:

- S: seawater, B: brackish water, F: fresh water;
- CV3: test Water (IMO soup) at day 0;
- CV7: treated water during ballasting and deballasting at day 0, day 1 and day 5;
- CV6: control water during ballasting and deballasting at day 0, day 1 and day 5; and
- before neutralization: treated water during deballasting at day 0, day 1 and day 5, treated water before neutralization process sampled from the tank directly.

Collection of field samples was undertaken by staff of Korea Marine Equipment Research Institute (KOMERI) and NeoEnBiz Co. using standard water sample collection methods and in accordance with the Guidelines (G8). Standard operating procedures (SOPs) were employed to provide consistency and reproducibility of the sampling methods in the tests, as outlined in the Quality Assurance Project Plan (QAPP).

2.5.3 Efficacy testing

Assurance of fulfilment of water quality test criteria and bio-efficacy testing was conducted by KOMERI, in accordance with its ISO/IEC 17025 quality system and the IMO Guidelines (G8). Full details are contained in the QAPP.

2.5.4 Chemical analysis

At each sampling event, the Active Substance (TRO as Cl_2) was measured in situ immediately after sampling using the DPD method with titration. Samples for the analysis of Relevant Chemicals (DBPs) were transported to the laboratory of LabFrontier Co. Ltd.

The analytical laboratory services for the measurement of DBPs using the discharge water samples from the BlueZone™ BWMS were carried out in accordance with internationally recognized guidelines (OECD or equivalent) and the quality system of ISO/IEC 17025. Full details are contained in the QAPP.

2.5.5 Whole Effluent Toxicity (WET) testing

WET testing was carried out by NeoEnBiz Co. in accordance with internationally recognized guidelines (OECD or equivalent) and an international quality assurance system (GLP). This testing aims to assess the residual toxicity of whole effluent ballast water after treatment by the BlueZone™ BWMS, in accordance with the Procedure (G9).

In accordance with Procedure (G9), the following ecotoxicity tests were performed:

- population growth inhibition test with microalgae;
- survival and population growth test with rotifer (invertebrates); and
- survival and growth test with fish (vertebrates).

2.6 Quality Control and Assurance (G9: 4.2.4)

Quality Control and Assurance (QA/QC) are of primary importance. The essential goal is to deliver reliable analytic results of defined quality. All testing processes in analytical laboratories contain a rigorous quality control and assurance programme consisting of a Quality Management Plan (QMP) and a Quality Assurance Project Plan (QAPP).

All analyses were carried out in accordance with standard methods as described in standard operating procedures of testing laboratories, of KOMERI, LabFrontier (LF) Co. Ltd. and NeoEnBiz Co. (NEB). The KOMERI laboratory is accredited by KOLAS for zooplankton, phytoplankton and micro-organism analyses. The KOMERI, as a director of this project, is accredited by IOC-UNESCO for identification of harmful microalgae (appendix II). The LF laboratory is accredited by KOLAS for chemical analysis of environmental samples (appendix III). Although the NeoEnBiz Institute is not accredited specifically for toxicological testing, it has an ecotoxicology laboratory, personnel with solid experience in toxicological research funded by various agencies including the Korean government (e.g. Ministry of Land, Transport and Maritime Affairs) and all of WET tests were performed according to GLP. The data for quality assurance (QA) are provided for each test report (appendix IV).

3 APPLICATION DATA-SET

3.1 Description of the BlueZone™ BWMS

The BlueZone™ BWMS is a system that disinfects ballast water of ships from aquatic organisms and pathogens using micro-sized ozone bubbles and neutralizes using thiosulfate solution.

The BlueZone™ BWMS consists of following modules:

- .1 ozone generation module;
- .2 mainstream ozone micro-bubble module (MOMB module), (ozone bubble generation device and collision and mixing device);
- .3 neutralization module; and
- .4 monitoring and control module.

Figure 3.1 shows the schematic process diagram of the BlueZone™ BWMS.

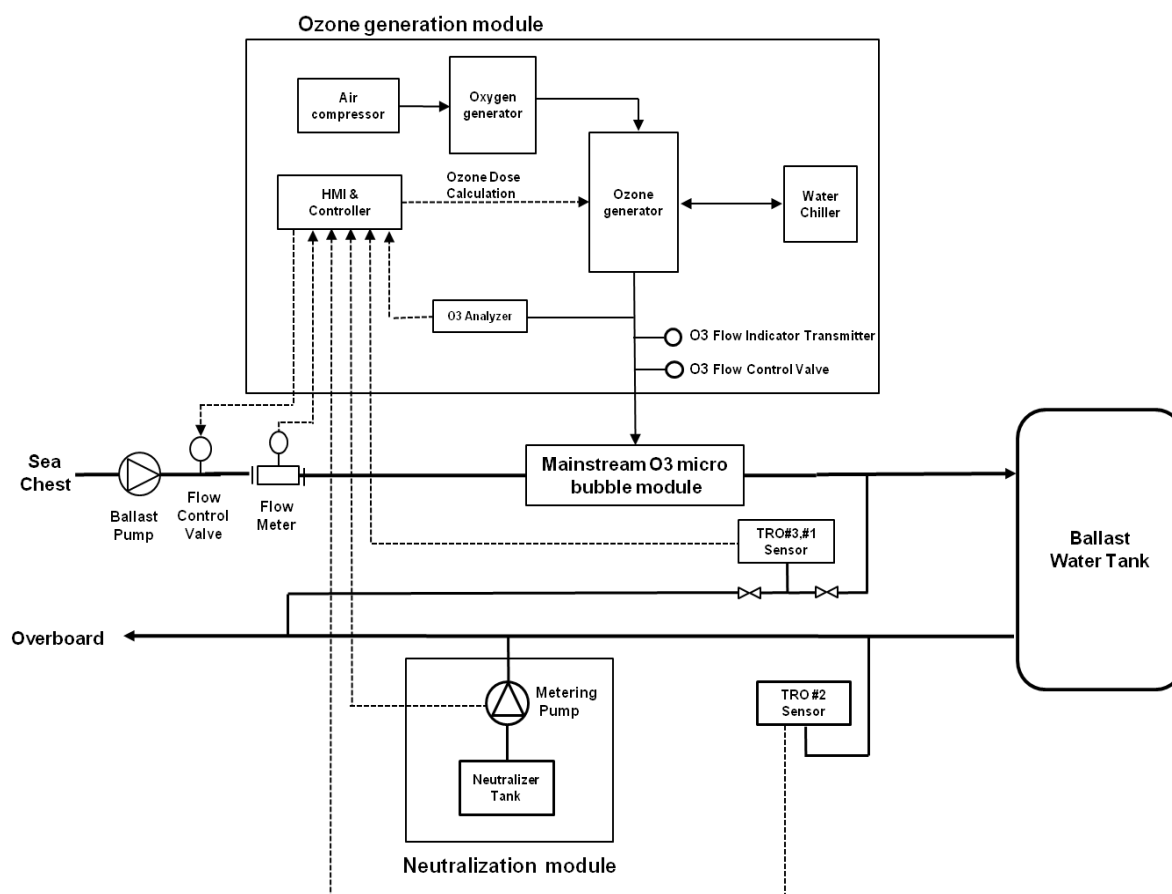


Figure 3.1: Schematic process diagram of the BlueZone™ BWMS

TRO concentration was automatically controlled by HMI (human machine interface) and PLC (programmable logic controller). To control the maximum TRO at less than 2.3 mg/L as Cl₂ automatically, parameters should be input to the PLC by the operator.

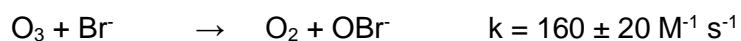
3.1.1 System working principles

In the BlueZone™ BWMS, the air compressor compresses the ambient air and discharges compressed air into the oxygen generator. By removing nitrogen from the compressed air inside the oxygen generator, purified oxygen is produced. The purified oxygen then passes through the ozone generator to produce ozone, which is injected into ballast water through a micro bubble nozzle to disinfect it from aquatic organisms. When ozone reacts with bromide ion in ballast water, TRO composed of hypobromous acid (HOBr) and hypobromite ion (OBr⁻) is produced.

The Active Substance (AS) of the BlueZone™ BWMS is ozone. The ozone dose determined by O₃ product (g/hr) and ballast flow rate (m³/hr) is measured with sensors.

The chemical reactions of ozonation

In seawater, the primary reactions of ozone are as follows:



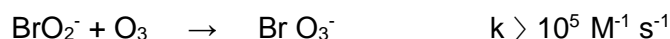
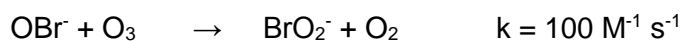


Figure 3.2 shows the primary reactions of the ozone and bromide ions in the seawater.

HOBr and OBr⁻ form an equilibrium in a quick reaction with the ozone.

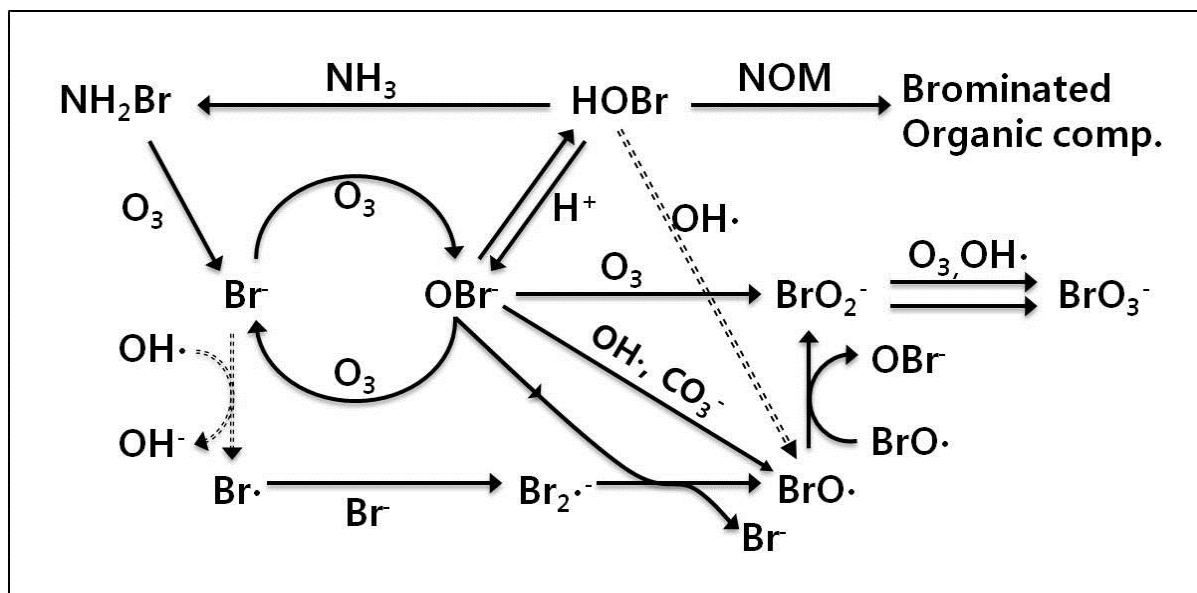
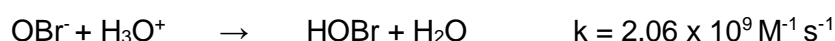
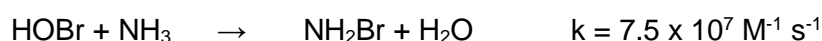
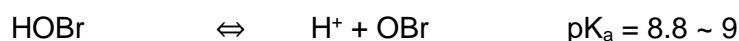


Figure 3.2: Primary reaction of ozone and bromide ion in seawater

The primary reactions of HOBr and OBr were as follows:

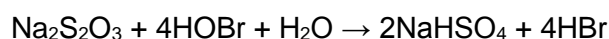
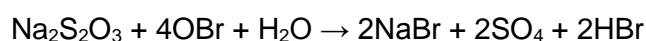
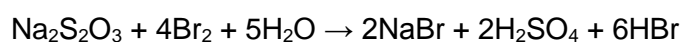


The chemical reactions of neutralization

TRO remaining in the ballast tank is neutralized by thiosulfate solution during the deballasting process.

Thiosulfate solution (300 g of sodium thiosulfate dissolved in 1 L of distilled water) has multiple reactions with chlorine or bromine species. It is an effective means (mechanism) for the removal of any combined chlorine or bromine species such as chloramines or bromamine. The chemical reactions are shown below:

Sodium thiosulfate:



Regarding water condition and initial TRO level, the required dosing rate to maintain the concentration of TRO was determined at 1.9 in light of the end point of the neutralization.

The injected thiosulfate solution is approved to chemically reduce any residual oxidants and is expected to be in the form of thiosulfate ion ($S_2O_3^{2-}$).

3.1.2 Ozone generation module

Ozone can be produced in several ways. Among various methods corona discharge is the most widely used method in the ozone production industry. The commercial ozone generator used in the land-based test for IMO Final Approval of the BlueZone™ BWMS was a medium frequency and silent corona discharge type of generator.

3.1.3 Mainstream O_3 micro-bubble module (MOMB module)

The MOMB module consists of the ozone bubble generation device and the collision and mixing device. In the ozone bubble generation device, the ozone is injected by the micro bubble nozzle and driving water pump to produce micro-sized ozone bubbles.

In the collision and mixing device, the micro-sized ozone bubbles spread into and mix with seawater. The aquatic organisms can be injured by collisions in this device.

3.1.4 Neutralization module

The neutralization module mainly consists of a neutralizer storage tank, metering pump (chemical dosing pump) and injection nozzle equipped with back pressure valve. Neutralizing agent is injected directly into the ballast water via pipe and metering pump. The neutralization module of the BlueZone™ BWMS is designed so that ballast water would be discharged to maintain the TRO value of less than the MADC, 0.2mg/L as Cl_2 .

To prevent discharge of the high concentrated TRO at the beginning of deballasting, the neutralizer solution is injected as soon as the deballast valve opens. The initial injection rate of the neutralizer solution is set at 80 mL/min for neutralizing MD (2.3 mg/L TRO as Cl_2) for the first 2 minutes of deballasting. After all conditions are under stable state, a calculated volume of neutralizer corresponding to the value of TRO is injected. The volume of neutralizer is calculated with the formulas below:

- .1 required neutralizer (g/hr) = Deballasting flow rate (m^3/hr) x TRO (g/m^3) x neutralizer dose ratio (1.9);
- .2 neutralizer low rate (L/hr) = required neutralizer (g/hr) / neutralizer concentration (g/L); and
- .3 neutralizer concentration (g/L) = 300 g/L as $S_2O_3^{2-}$.

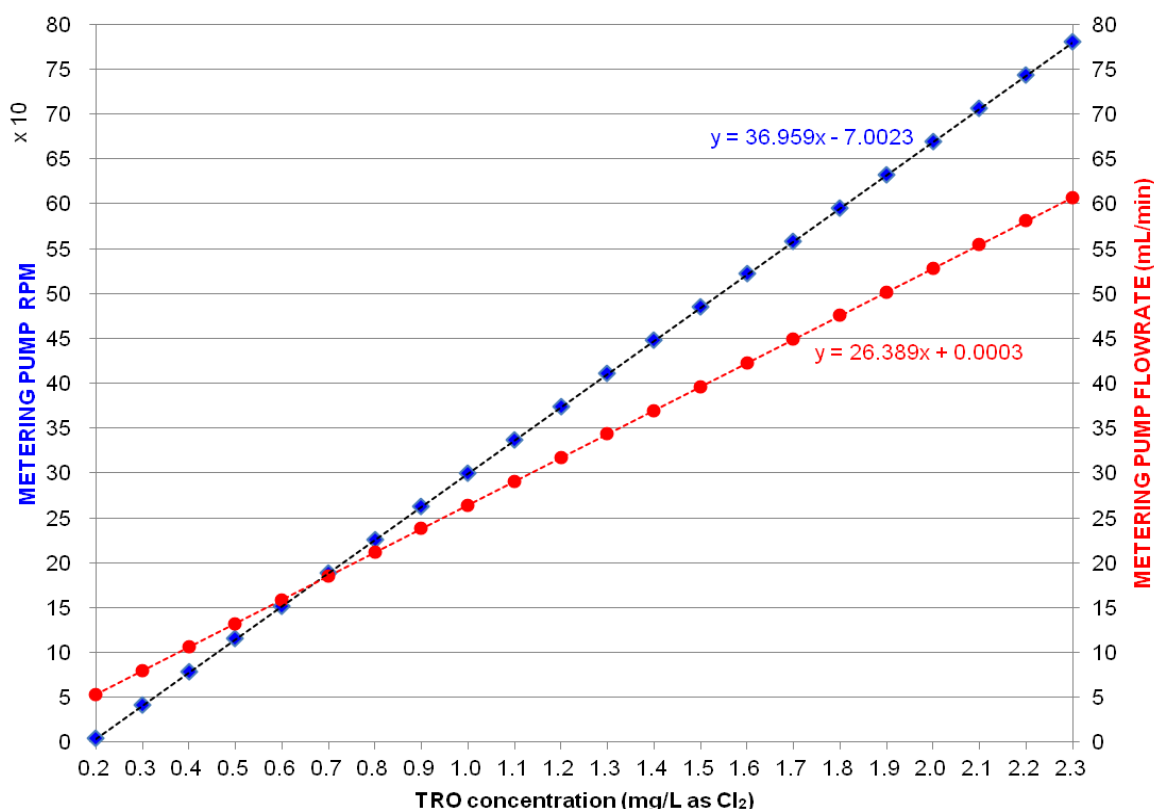


Figure 3.3: Relationship between TRO degradation and RPM (revolutions per minute) or flow rate (mL/min) of the metering pump

Correlation between RPM or flow rate (mL/min) of the metering pump and TRO mg/L as Cl₂ obtained by the performance curve of the metering pump is shown in figure 3.3.

During the initial 2 minutes of deballasting, TRO is not detected due to the sensor's measurement interval. Therefore, the injection rate of the neutralizer solution is set at 80 mL/min for neutralizing MD (2.3 mg/L TRO as Cl₂) for the first 2 minutes of deballasting. The initial injection rate (80 mL/min) is obtained by multiplying the calculated value (60 mL/min) by a safety factor (1.3).

3.1.5 Monitoring and control module

The performance of the BlueZone™ BWMS is monitored and controlled by the HMI and PLC (model CREVIS NA-9173). The data acquired from each measuring instrument can be used as a communicator between each of the measuring instruments and PC screen using the MODBUS RS485. All measurements and control values are continuously recorded in the "logged data from test cycles" contained in appendix XIII, in real-time during operation.

3.2 Introduction of application data

This dossier contains the information specified in Procedure (G9). For Active Substances and/or Preparations including any of its components as appropriate, data on properties is included. For Relevant Chemicals, data are provided as well. Literature review and testing on fate and effect were performed with the laboratory scale test with Active Substances and Preparations (G9: 5.3.1). Any reference to specific test methods in the following is indicative with the purpose of providing guidance to an Administration on possible methods that were considered. Other internationally recognized test methods were used as well.

3.3 Identification of the Active Substances or Preparation (G9:2.1)

3.3.1 Preparations

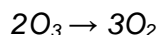
Preparation means any commercial formulation containing one or more Active Substances including any additives.

As outlined above, the BlueZone™ BWMS does not involve the formulation of any Preparation for carriage on board the ship for use in the BWMS. Rather, the Active Substance as ozone is generated on board as required.

Strictly speaking then, the micro ozone bubble is the Active Substance of relevance to the BlueZone™ BWMS. The by-products of ozone are collectively referred to as disinfection by-products (DBPs), and may be considered as Relevant Chemicals. However, as stated above, for the purposes of this application and the whole effluent testing that has been conducted to support it, Preparation, Active Substance and Relevant Chemicals, as well as ballast water discharge, all have the same meaning. This whole effluent approach has been adopted for other oxidant-based BWMS that have been granted Final Approval by MEPC. Nevertheless, relevant data as required by Procedure (G9) are provided below for the Active Substance and Relevant Chemicals.

3.3.2 Active Substance

Ozone is defined as Active Substance (AS) in the BlueZone™ BWMS (table 3.1). Ozone is a molecule that consists of three negatively charged oxygen atoms. The ozone molecule is very unstable and has a short half-life, causing it to fall back into its original form after a while, according to the following reaction mechanism:



The ozone generator can create ozone artificially by means of extremely high voltages, as used here. Ozone is a powerful oxidant able to achieve disinfection with less contact time and concentration than all weaker disinfectants, such as chlorine, chlorine dioxide, and monochloramine (Demers and Renner, 1992).

Table 3.1: Identification of Active Substance

Chemicals	CAS no.	Molecular weight	Chemical formula
Ozone	10028-15-6	47.98	O ₃

TRO (total residual oxidant) was monitored instead of the concentration of ozone in treated water, which was used to control the injection concentration of ozone into the ballasting line. TRO was measured in situ by CLX online (HF Scientific, United States), which applied ISO 73932(1985) / APHA standard Methods for the Examination of Water and Wastewater (21st Edition, 2005) Method 4500-Cl G DPD Colorimetric Method. In the analyses of the treated water, the concentrations of TRO are given as Cl₂. Also, TRO measurement was internally performed with a standard DPD colorimetric method (US EPA Method 330.5) with other chemical analysis.

3.3.3 Relevant Chemicals (G9: 2.1.4)

During the process of disinfection using the ozone generation module, disinfection by-products (DBPs) such as oxyhalide anions, trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitriles (HANs) and other halogenated chemicals can be produced by the reaction of TROs with organic matter. These DBP chemicals are classified as Relevant Chemicals (RC). Thiosulfate solution used in the neutralizing process is also included in RCs (table 3.2).

Table 3.2: Identification of Relevant Chemicals

Chemicals	CAS no.	Molecular weight	Chemical formula
Oxyhalide anions			
Bromate	15541-45-4	127.90	BrO_3^-
Chlorate	14866-68-3	83.45	ClO_3^-
Perchlorate	14797-73-0	99.45	ClO_4^-
THMs (Trihalomethanes)			
Dibromochloromethane	124-48-1	208.29	CHBr_2Cl
Dichlorobromomethane	75-27-4	163.80	CHBrCl_2
Tribromomethane (bromoform)	75-25-2	252.77	CHBr_3
Trichloromethane (chloroform)	67-66-3	119.38	CHCl_3
HAAs (Haloacetic acids)			
Monochloroacetic acid	79-11-8	94.50	$\text{C}_2\text{H}_3\text{ClO}_2$
Dichloroacetic acid	79-43-6	128.90	CHCl_2COOH
Trichloroacetic acid	76-03-9	163.40	CCl_3COOH
Monobromoacetic acid	79-08-3	138.95	$\text{C}_2\text{H}_3\text{BrO}_2$
Dibromoacetic acid	631-64-1	217.84	Br_2CHCOOH
Tribromoacetic acid	75-96-7	296.74	$\text{C}_2\text{HBr}_3\text{O}_2$
Bromochloroacetic acid	5589-96-8	173.39	$\text{C}_2\text{H}_2\text{BrClO}_2$
Dibromochloroacetic acid	5278-95-5	252.29	$\text{C}_2\text{HBr}_2\text{ClO}_2$
Dichlorobromoacetic acid	71133-14-7	207.84	$\text{C}_2\text{HBrCl}_2\text{O}_2$
HANs (Haloacetonitriles)			
Chloropicrin	76-06-2	164.38	CCl_3NO_2
Monobromoacetonitrile	590-17-0	119.95	$\text{C}_2\text{H}_2\text{BrN}$
Dibromoacetonitrile	3252-43-5	198.84	Br_2CHCN
Other halogenated chemicals			
2,4,6-Tribromophenol	118-79-6	330.80	$\text{C}_6\text{H}_3\text{Br}_3\text{O}$
1,2,3-Trichloropropane	96-18-4	147.43	$\text{C}_3\text{H}_5\text{Cl}_3$
Neutralizer			
Sodium thiosulfate	7772-98-7	158.11	$\text{Na}_2\text{S}_2\text{O}_3$

Different sample types were control and treated water under seawater, brackish water and fresh water conditions at day 0, day 1 and day 5. Chemical analyses at day 0, day 1 and day 5 done before and after neutralization were evaluated for DBPs as Relevant Chemicals. The data are presented in tables 3.3 and 3.4. The concentrations of Relevant Chemicals associated with the BlueZone™ BWMS were shown similar among the three types of water samples, except for a relatively higher concentration of dibromoacetonitrile in day 0 of seawater before neutralization.

Table 3.3: The concentration (µg/L) of Relevant Chemicals of the BlueZone™ BWMS under seawater (33 PSU) and brackish water (21 PSU) conditions

Name of chemical substance	^a MDL	Test water	Elapsed time (day) and concentration								
			Day 0			Day 1			Day 5		
			Control water	^b Treated water		Control water	^b Treated water		Control water	^b Treated water	
				Before N	After N		Before N	After N		Before N	After N
Seawater (33 PSU)											
Oxyhalide anions											
Bromate	1.2	6.64	6.31	20.41	20.10	3.92	21.57	23.90	6.12	18.43	21.94
Chlorate	60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60
Perchlorate	2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09
Trihalomethanes											
Dibromochloromethane	0.56	< 0.56	< 0.56	< 0.56	< 0.56	< 0.56	1.95	1.68	< 0.56	2.02	1.87
Dichlorobromomethane	0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55
Bromoform	0.61	< 0.61	< 0.61	30.87	38.15	< 0.61	89.15	79.38	< 0.61	92.80	87.71
Chloroform	0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99
Haloacetic acids											
Monochloroacetic acid	0.04	0.61	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Dichloroacetic acid	0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Trichloroacetic acid	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Monobromoacetic acid	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Dibromoacetic acid	0.01	3.20	3.19	20.47	11.84	2.91	16.22	13.01	2.40	3.75	4.06
Tribromoacetic acid	0.02	1.34	< 0.02	3.13	2.31	1.38	3.33	2.72	1.04	2.56	2.03
Bromochloroacetic acid	0.09	< 0.09	< 0.09	1.52	< 0.09	< 0.09	1.37	1.20	< 0.09	1.59	< 0.09
Dibromochloroacetic acid	0.02	1.64	< 0.02	16.31	2.95	1.71	3.17	2.48	< 0.02	3.07	2.48
Dichlorobromoacetic acid	0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Haloacetoneitriles											
Chloropicrin	0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Monobromoacetoneitrile	0.06	< 0.06	< 0.06	2.16	8.03	< 0.06	22.52	23.53	< 0.06	< 0.06	< 0.06
Dibromoacetoneitrile	0.08	< 0.08	< 0.08	673.91	2.48	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Other halogenated chemicals											
2,4,6-Tribromophenol	0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
1,2,3-Trichloropropane	0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73
Thiosulfate	500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500
Brackish water (21 PSU)											
Oxyhalide anions											
Bromate	1.2	19.51	15.76	33.55	34.91	19.20	39.05	35.47	12.13	39.82	34.19
Chlorate	60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60
Perchlorate	2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09
Trihalomethanes											
Dibromochloromethane	0.56	< 0.56	< 0.56	2.31	2.40	< 0.56	3.73	3.74	< 0.56	3.99	3.44
Dichlorobromomethane	0.55	2.99	2.96	3.19	3.16	3.23	3.93	3.89	2.96	4.05	3.40
Bromoform	0.61	< 0.61	< 0.61	16.55	21.36	< 0.61	62.31	63.02	< 0.61	65.57	48.81
Chloroform	0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99	< 0.99
Haloacetic acids											
Monochloroacetic acid	0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	1.05	< 0.04	< 0.04
Dichloroacetic acid	0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Trichloroacetic acid	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Monobromoacetic acid	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Dibromoacetic acid	0.01	1.90	1.36	17.72	12.29	1.56	9.60	30.61	7.12	14.22	4.10
Tribromoacetic acid	0.02	< 0.02	< 0.02	4.70	4.86	< 0.02	< 0.02	5.23	< 0.02	2.96	< 0.02

Bromochloroacetic acid	0.09	< 0.09	1.53	1.98	1.90	< 0.09	2.35	2.64	1.90	2.12	1.27
Dibromochloroacetic acid	0.02	1.90	1.36	17.72	12.29	1.56	9.60	30.61	7.12	14.22	4.10
Dichlorobromoacetic acid	0.03	< 0.03	< 0.03	0.95	< 0.03	< 0.03	< 0.03	1.03	1.03	0.81	< 0.03
Haloacetonitriles											
Chloropicrin	0.06	1.54	1.68	< 0.06	1.93	< 0.06	1.39	1.40	< 0.06	1.40	< 0.06
Monobromoacetonitrile	0.06	< 0.06	< 0.06	0.75	3.97	< 0.06	4.39	4.41	< 0.06	1.51	0.99
Dibromoacetonitrile	0.08	< 0.08	< 0.08	57.56	23.80	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Other halogenated chemicals											
2,4,6-Tribromophenol	0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
1,2,3-Trichloropropane	0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73
Thiosulfate	500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500

^a MDL (method detection limit).

^b Treated water is divided into two types, before and after neutralization (of the discharge treated water).
N: Neutralization.

Table 3.4: The concentration of Relevant Chemicals (µg/L) of the BlueZone™ BWMS under fresh water (< 3 PSU) condition

Name of chemical substance	^a MDL	Test water	Elapsed time (day) and concentration								
			Day 0			Day 1			Day 5		
			Control water	^b Treated water		Control water	^b Treated water		Control water	^b Treated water	
				Before N	After N		Before N	After N		Before N	After N
Fresh water (< 3 PSU)											
Oxyhalide anions											
Bromate	1.2	< 1.20	< 1.20	13.99	13.94	< 1.20	15.90	11.79	< 1.20	14.18	11.22
Chlorate	60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60
Perchlorate	2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09	< 2.09
Trihalomethanes											
Dibromochloromethane	0.56	1.06	< 0.56	1.51	1.03	1.05	2.90	2.46	1.02	3.67	3.18
Dichlorobromomethane	0.55	4.91	3.85	5.65	3.82	4.24	6.03	5.01	4.36	6.54	5.52
Bromoform	0.61	2.45	1.91	8.67	6.36	2.10	47.37	43.00	2.61	89.72	78.57
Chloroform	0.99	13.79	10.93	15.81	10.47	12.92	14.56	11.84	13.50	15.11	12.26
Haloacetic acids											
Monochloroacetic acid	0.04	0.06	0.07	0.06	0.08	0.06	0.06	0.07	0.06	0.06	< 0.04
Dichloroacetic acid	0.02	< 0.02	0.45	0.53	0.50	0.43	0.49	0.50	0.45	0.49	0.38
Trichloroacetic acid	0.01	< 0.01	< 0.01	< 0.01	1.04	< 0.01	< 0.01	0.85	< 0.01	< 0.01	0.53
Monobromoacetic acid	0.01	0.30	0.30	0.34	0.31	0.30	0.35	0.33	0.30	0.36	< 0.01
Dibromoacetic acid	0.01	0.66	0.68	1.21	0.91	0.65	1.07	1.04	0.68	1.11	< 0.01
Tribromoacetic acid	0.02	0.74	0.74	0.80	0.75	2.92	0.80	0.80	0.74	0.82	0.76
Bromochloroacetic acid	0.09	0.84	0.92	0.55	4.33	< 0.09	0.72	2.85	0.82	0.71	0.48
Dibromochloroacetic acid	0.02	0.74	0.75	2.05	0.75	0.73	1.06	0.84	0.75	1.05	1.67
Dichlorobromoacetic acid	0.03	< 0.03	0.75	0.75	0.75	< 0.03	0.75	< 0.03	0.75	0.75	0.75
Haloacetonitriles											
Chloropicrin	0.06	0.81	1.05	0.87	0.63	0.65	0.83	0.68	0.51	0.73	0.64
Monobromoacetonitrile	0.06	0.51	0.51	0.46	0.56	0.47	0.48	0.75	0.46	0.47	0.48
Dibromoacetonitrile	0.08	0.39	0.39	5.95	< 0.08	0.29	7.36	1.00	< 0.08	6.70	7.09

Name of chemical substance	^a MDL	Test water	Elapsed time (day) and concentration								
			Day 0			Day 1			Day 5		
			Control water	^b Treated water		Control water	^b Treated water		Control water	^b Treated water	
				Before N	After N		Before N	After N		Before N	After N
Other halogenated chemicals											
2,4,6-Tribromophenol	0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
1,2,3-Trichloropropane	0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73	< 0.73
Thiosulfate	500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500	< 500

^a MDL (method detection limit).

^b Treated water is divided into two types, before and after neutralization (of the discharge treated water).
N: Neutralization.

3.4 Data on the efficacy of organism removal by the BlueZone™ BWMS

3.4.1 Preparation for the test

3.4.1.1 Cleaning tanks and pipes

The water tanks and pipes were cleaned with tap water after each use to remove dirt and residues left over in the tanks. Several hours before a new test took place, tap water was pumped into each ballast water tank and drained in order to prevent contamination from affecting the outcomes.

3.4.1.2 Test water

Test water was prepared in a 500 m³ tank using saline seawater (> 32 PSU) from Jangmok Bay, brackish water which was made with the addition to seawater (3-32 PSU) of tap water that has been aerated overnight to remove any residual chlorine (0 ppm).

The combination of indigenous organisms and cultured surrogate species (> 50 µm: *Artemia salina*, 10 - 50 µm: *Tetraselmis* spp.) were added to meet the biological concentration criteria. One or more cultured species were used at a time depending on the abundance of harvested indigenous organisms and culture conditions. Soluble glucose, soluble starch and silica sand were added to increase the initial concentrations of dissolved organic carbon (DOC), particulate organic carbon (POC) and total suspended solids (TSS) to meet chemical water quality criteria.

3.4.2 Test methods

Three sets of separate nets were used for concentrating organisms into the net (each set uses 2 types of net; 7 µm mesh and 45 µm mesh in diagonal dimension) to avoid cross-contamination. All tests and analyses were performed in accordance with Guidelines (G8) by internationally accredited laboratories (ISO/IEC 17025). Table 3.5 shows analytical methods.

Table 3.5: Test methods

Parameter	Methods
Basic water parameter	
Salinity	APHA Standard Method ^a 2520B
Dissolved oxygen	ASTM D888-09 Test Method C
Water temperature	APHA Standard Method 2550
pH	APHA Standard Method 4500-H ⁺ B
Oxidation-reduction potential	APHA Standard Method 2580
Total organic carbon	ISO 8245:1999
Dissolved organic carbon	ISO 8245:1999
Total suspended solid	APHA Standard Method 2540 D
Turbidity	APHA Standard Method 2130 D
Efficacy test	
≥ 50 µm Organism	Fleming and Coughlan (1978) ^b US EPA 600/R-10/146 (2010) ^c APHA Standard Method 10200 C
≥ 10-50 µm Organism	Anja et al. (2005) ^d APHA Standard Method 10200 C Manual and Guide, UNESCO (2005) UNESCO 4 (2003) US EPA 445.0:1997
Heterotrophic bacteria	APHA Standard Method 9215
Coliform	APHA Standard Method 9222 B
<i>Escherichia coli</i>	US EPA 1603:2009
Intestinal Enterococci	US EPA 1600:2009
Toxicogenic <i>Vibrio cholerae</i> (O1, O139)	APHA Standard Method 9260 H
TOC (DOC/POC)	ISO 8245:1999

Test water quality of each test is summarized in table 3.6.

Table 3.6: A brief summary of water qualities of the test waters for the land-based test

Test water	Test date	Temp. (°C)	Salinity (PSU)	DOC (mg/L)	POC (mg/L)	TSS (mg/L)	pH	DO (mg/L)	Turbidity (NTU)
Seawater (33 PSU)	17 Jul. 2013	25.30 ^a ± 0.11 ^b	33.64 ± 0.16	3.00 ± 0.04	1.80 ± 0.26	24.5 ± 3.75	7.96 ± 0.02	6.74 ± 0.04	4.18 ± 0.28
	24 Jul. 2013	25.16 ± 0.09	33.56 ± 0.18	3.03 ± 0.12	1.35 ± 0.39	25.0 ± 1.61	7.98 ± 0.01	6.80 ± 0.02	4.84 ± 0.47
	28 Aug. 2013	25.08 ± 0.05	33.71 ± 0.06	3.25 ± 0.03	1.44 ± 0.35	19.6 ± 1.33	7.93 ± 0.02	6.86 ± 0.01	4.19 ± 0.40
	4 Sep. 2013	24.23 ± 0.12	32.85 ± 0.20	3.39 ± 0.12	1.87 ± 0.07	23.6 ± 2.17	7.92 ± 0.01	6.89 ± 0.03	4.70 ± 0.27
	11 Sep. 2013	24.64 ± 0.45	33.49 ± 0.13	2.98 ± 0.04	1.94 ± 0.39	30.7 ± 5.89	7.97 ± 0.03	7.25 ± 0.06	4.57 ± 0.29
Brackish water (21 PSU)	12 Jun. 2013	20.46 ± 0.12	20.54 ± 0.05	7.65 ± 0.02	8.97 ± 0.97	63.6 ± 4.13	7.95 ± 0.02	7.95 ± 0.03	20.13 ± 0.64
	26 Jun. 2013	22.38 ± 0.04	21.41 ± 0.03	7.34 ± 0.04	6.79 ± 0.52	55.2 ± 5.79	7.98 ± 0.02	7.43 ± 0.01	18.73 ± 0.77
	25 Sep. 2013	24.80 ± 0.11	21.13 ± 0.04	8.10 ± 0.06	7.45 ± 0.21	56.4 ± 7.35	8.23 ± 0.01	7.25 ± 0.02	16.22 ± 0.98
	11 Oct. 2013	23.89 ± 0.04	21.61 ± 0.04	7.88 ± 0.55	6.96 ± 0.35	58.2 ± 5.07	7.60 ± 0.01	8.48 ± 0.12	20.38 ± 0.73
	23 Oct. 2013	21.33 ± 0.10	21.25 ± 0.06	7.57 ± 0.04	6.31 ± 0.59	114.6 ± 14.37	8.20 ± 0.01	7.83 ± 0.02	18.49 ± 1.43
Fresh water (< 3 PSU)	11 Dec. 2013	11.18 ± 0.18	2.73 ± 0.02	7.15 ± 0.19	5.02 ± 0.17	63.00 ± 4.00	7.40 ± 0.03	6.53 ± 0.10	11.82 ± 2.37

3.4.3 Test results

All efficacy test results for the discharged treated water and control water satisfied regulation D-2 in Guidelines (G8).

3.5 Data on effects on aquatic plants, invertebrates and fish, and other biota, including sensitive and representative organisms (G9: 4.2.1.1)

3.5.1 Acute aquatic toxicity

Existing ecotoxicity data were reviewed to find aquatic ecotoxicity data for Relevant Chemicals as DBPs associated with the BlueZone™ BWMS (appendix IV). The data for ecotoxicity from the literature are provided as supporting information and discussed in relation to the Predicted No Effect Concentration (PNEC) derivation in section 6.3.3.

No new information, please refer to section 3.5.1 of the annex to document MEPC 65/2/5.

3.5.2 Chronic aquatic toxicity

No new information, please refer to section 3.5.2 of the annex to document MEPC 65/2/5.

3.5.3 Endocrine disruption

No new information, please refer to section 3.5.3 of the annex to document MEPC 65/2/5.

3.5.4 Sediment toxicity

No new information, please refer to section 3.5.4 of the annex to document MEPC 65/2/5.

3.5.5 Food web/population effects

No new information, please refer to section 3.5.5 of the annex to document MEPC 65/2/5.

3.5.6 Data on mammalian toxicity (G9: 4.2.1.2)

No new information, please refer to section 3.6 of the annex to document MEPC 65/2/5.

3.5.7 Acute toxicity

No new information, please refer to section 3.6.1 of the annex to document MEPC 65/2/5.

3.5.8 Effects on skin and eye

No new information, please refer to section 3.6.2 of the annex to document MEPC 65/2/5.

3.5.9 Repeated-dose toxicity

No new information, please refer to section 3.6.3 of the annex to document MEPC 65/2/5.

3.5.10 Chronic toxicity

No new information, please refer to section 3.6.4 of the annex to document MEPC 65/2/5.

3.5.11 Developmental and reproductive toxicity

No new information, please refer to section 3.6.5 of the annex to document MEPC 65/2/5.

3.5.12 Carcinogenicity

No new information, please refer to section 3.6.6 of the annex to document MEPC 65/2/5.

3.5.13 Mutagenicity / genotoxicity

No new information, please refer to section 3.6.7 of the annex to document MEPC 65/2/5.

3.5.14 Toxicokinetics

No new information, please refer to section 3.6.8 of the annex to document MEPC 65/2/5.

3.6 Data on environmental fate and effect under aerobic and anaerobic conditions (G9: 4.2.1.3)

3.6.1 Modes of degradation (biotic; abiotic)

Ozone as Active Substance decomposes spontaneously during water treatment by a complex mechanism that involves the generation of hydroxyl free radicals. The hydroxyl free radicals are among the most reactive oxidizing agents in water. This is after all their mechanism of action and how they produce an oxidizing environment. As a consequence of this oxidizing environment, along with the presence of organic matter, THMs and HAAs are also produced. Biotic degradation for all of these simple halogenated organic compounds is on the order of days to weeks. Abiotic degradation of these compounds is longer. On the other hand, the half-life of hydroxyl free radicals is in the order of microseconds.

Degradation of TRO has two major routes: (1) through a quick consumption or decomposition by the chlorine demand in the water (organic and nitrogen compounds, ions of Fe, Ni, Co that decompose TRO); and (2) through a slow decay via photolytic or heat decomposition.

In case of disinfection by ozone, HOBr/OBr⁻ form an equilibrium in a quick reaction with the ozone. HOBr/OBr⁻ is removed from seawater by several mechanisms. HOBr/OBr⁻ will react with natural organic matter to form tribromomethane by the haloform reaction. In fact, a number of disinfection by-products and other halogen containing compounds are reported when bromide is present in natural waters. Therefore, organic matter in ballast water could lead to the disappearance of the TRO. Sunlight can reduce HOBr/OBr⁻ to Br⁻ through a complex series of photochemical reactions. In some cases, where high concentrations of Cl⁻ are present, it may be that sunlight-mediated photolysis of HOBr/OBr⁻ leads to the formation of bromate ion. Therefore, photolysis may also lead to the loss of TRO.

The decay of TRO strongly influences the biological efficacy of the Active Substance as ozone aimed to eliminate organisms present in ballast water. Seawater characteristics, including the organic content and ammonia, affect the amount of ozone required to achieve a desired TRO level and rate of TRO decay, and therefore, need to be considered in determining ozone requirements for ballast water treatment.

The rate of TRO decay seems dependent on salinity. Two other obvious effects would arise from differences in the organic carbon and/or ammonia concentrations, and these are not sufficiently different to account for the differences in decay rate. Seawater from different sources has different concentrations of chemical compounds that affect TRO decay rates (table 3.7). No neutralization was done given the discharge water TRO was < 0.2 ppm.

**Table 3.7: Variation of TRO concentrations with different test conditions
(data from chemical analysis in appendix III)**

Salinity	Test Date	(mg/L TRO as Cl ₂)		
		Day 0	Day 1	Day 5
Seawater (33 PSU)	11 Sep. 2013	0.64 ± 0.01	0.11±0.01	< 0.02
Brackish water (21 PSU)	11 Oct. 2013	1.02 ± 0.01	0.13±0.01	< 0.02
Fresh water (< 3 PSU)	11 Dec. 2013	1.17±0.01	0.33±0.00	0.12±0.01

3.6.2 Persistence and identification of the main metabolites in the relevant media (ballast water, seawater and fresh waters)

Due to the rapid degradation, Active Substances are not considered to be persistent in ballast water, marine or fresh water of receiving ports. Furthermore, due to low BCF and K_{oc} values, Active Substances will not accumulate in the aquatic life and metabolites.

3.6.3 Bioaccumulation, partition coefficient, octanol/water partition coefficient

No new information, please refer to section 3.7.3 of the annex to document MEPC 65/2/5.

3.6.4 Bioavailability/biomagnification/bioconcentration

No new information, please refer to section 3.7.4 of the annex to document MEPC 65/2/5.

3.6.5 Reaction with organic matter

No new information, please refer to section 3.7.5 of the annex to document MEPC 65/2/5.

3.6.6 Potential physical effects on wildlife and benthic habitats

No new information, please refer to section 3.7.6 of the annex to document MEPC 65/2/5.

3.6.7 Potential residues in seafood

No new information, please refer to section 3.7.7 of the annex to document MEPC 65/2/5.

3.6.8 Any known interactive effects

No other interactive effects are known from the literature.

3.7 Physical and chemical properties for the Active Substances, Relevant Chemicals and treated ballast water (G9: 4.2.1.4)

3.7.1 Physical and chemical properties of the Substances

Available chemical property data for these three additional substances are provided in tables 3.8 and 3.9.

Table 3.8: Physical and chemical properties of Active Substance

Physical/Chemical Property	Abbreviation	Ozone
Melting point (°C)	MP	-193
Boiling point (°C)	BP	-112
Flammability (flash point for liquids; °C)	FL	Not applicable
Density (20°C; kg/m ³)	DS	Not applicable
Viscosity (20°C)	VS	Not applicable
Vapour pressure/Vapour density (air = 1)	VP	> 1 atm
Water solubility (temp; effect of pH; mg/L) / Dissociation constant (pKa)	WS	570 mg/L at 20°C
Henry's law constant	HL	2.431E-016 atm-m ³ /mole
Corrosivity to materials	CS	Corrosive
Oxidizing properties	OP	Strong oxidizing agent

Table 3.9: Physical and chemical properties of Relevant Chemicals

Chemicals	*MP	*BP	*FL	*DS	*VP	*WS	*HL	*CR	*OP
Bromate	206	517.3	Not found	Not found	5.53E-11 mmHg (25°C)	1000 g/L	1.135E-19 atm-m ³ /mole	Not found	Oxidizing agent
Chlorate	194.0	497.0	Not found	Not found	3.85E-12 (25°C)	1000 g/L	4.279E-19 atm-m ³ /mole	Not found	NA
Perchlorate	193.6	492.0	Not found	Not found	5.55E-12 (25°C)	1e+003 g/L	7.336E-19 atm-m ³ /mole	Not found	NA
Dibromochloro methane	-22	117.1	Non-flammable	2.504	21 mmHg (25°C)	2.7 g/L (20°C)	7.537E-3 atm-m ³ /mol	Not found	NA
Dichlorobromo methane	-55	89.7	Non-flammable	1.98 at 25°C	65.3 mmHg (25°C)	4.7 g/L (22°C)	9.614E-3 atm-m ³ /mole	Not found	NA
Bromoform	9	142.9	Non-flammable	2.974	5 mmHg (20°C)/8.7	3.1 g/L (25°C)	54.2 Pa.m ³ /mol (25°C, estimated)	Corrosive	NA
Chloroform	-63.5	61.3	Non-flammable	1.48	197 mmHg (25°C)	8.7 g/L (23°C)	367 Pa.m ³ /mol at 25°C	Corrosive	Strong oxidizing agent
Monochloroacetic acid	61-63	189	126°C (closed cup)	1.399	0.065 mmHg (25°C)/3.26	858 g/L (25°C)/pKa=2.87	9.42E-9 atm-m ³ /mole	Not found	NA
Dichloroacetic acid	9-11	194	113°C	1.575	0.179 mmHg (25°C)/4.45	Miscible with water/pKa=1.26	3.52E-7 atm-m ³ /mole	Corrosive	NA
Trichloroacetic acid	52-58	196.5	198°C	1.808	0.06 mmHg (25°C)	54 g/L (25°C)/pPa=0.51	1.35E-8 atm-m ³ /mole	Corrosive	NA
Monobromoacetic acid	47-49	207	113°C (closed cup)	2.003	0.119 mmHg (25°C)	1750 g/L (25°C)/pKa=2.89	8.88E-8 atm-m ³ /mole	Corrosive	NA
Dibromoacetic acid	32-38	238.4	113°C (closed cup)	2.627	0.023 mmHg (25°C)	2100 g/L (25°C)/pKa=1.48	7.27E-9 atm-m ³ /mole	Not found	NA
Tribromoacetic acid	131	245	Not found	3.099	0.009 mmHg (25°C)	1.1 g/L (25°C)	9.885E-8 atm-m ³ /mole	Corrosive	NA

Bromochloroacetic acid	35.69	244.6	110°C (closed cup)	2.138	0.14 mmHg (25°C)	250 g/L (25°C)/ pKa=1.4	2.22E-8 atm-m ³ /mole	Corrosive	NA
Dibromochloroacetic acid	68.1	217.7	Not found	2.685	0.05 mmHg (25°C)	2.4 g/L (25°C)	7.322E-7 atm- m ³ /mole	Not found	NA
Dichlorobromoacetic acid	47.9	234.6	Not found	2.225	0.134 mmHg (25°C)	4.9 g/L (25°C)	2.022E-6 atm- m ³ /mole	Not found	NA
Chloropicrin	-69.2	112.4	Not found	1.786	18 mmHg	1.058e+2 g/L (25°C)	1.382E-013 atm- m ³ /mole	Not found	Strong oxidizers
Dibromoacetone	6.98	203.6	Flammable	2.435	2.1 mmHg (25°C)	9.6 g/L (25°C)	8.203E-6 atm- m ³ /mole	Corrosive	NA
Monobromoacetone	-31.56	150	Not found	1.761	3.18 mmHg (25°C)	107 g/L (25°C)	1.849E-5 atm- m ³ /mole	Corrosive	NA
2,4,6-Tribromophenol	94	282-290	Not found	2.425	0.00146 mm Hg (25°C)	0.07 g/L (25°C)	1.445E-5 atm- m ³ /mole	Not found	NA
1,2,3-Trichloropropane	-46.9	162.2	Not found	Not found	3.69 mm Hg (25°C)	1.75 g/L (25°C)	6.251E-4 atm-m ³ /mole	Not found	strong caustics and oxidizers
Sodium thiosulfate	48.3	100	Non-flammable	1.667	negligible	210 g/L (20°C)	No data available	Not found	NA

* MP: Melting point (°C), BP: Boiling point (°C), FL: Flammability (flash point for liquids; °C), DS: Density (20°C; kg/m³), VP: Vapour pressure/Vapour density (air = 1), WS: Water solubility (temp; effect of pH; mg/L)/Dissociation constant (pKa), HL: Henry's law constant, CR: Corrosivity to materials, OP: Oxidizing properties ,NA: No data available

3.7.2 Corrosivity

A full corrosion test was carried out for 6 months in accordance with the recommendations provided in section 3.6.9 of the Methodology (BWM.2/Circ.13/Rev.1).

3.8 Analytical methods at environmentally relevant concentrations (G9: 4.2.1.5)

All analyses were done according to standard methods. The chemical analysis laboratory, LabFrontier Co. Ltd, is accredited by KOLAS for chemical analysis of environmental samples.

Treated ballast water samples were collected before and after neutralization at discharge. Samples for chemical analysis were stored in containers at 4°C and transported to the laboratory within 12 hours from collection. Acceptable field-testing analytical methods were also used where applicable (e.g. TRO as Cl₂). The methods used to determine DBP concentrations are listed in table 3.10. Information regarding quality assurance from the analytical laboratories is included in appendix IV.

Table 3.10: List of analytical methods for TRO and Relevant Chemicals (µg/L)

Relevant Chemical	*MDL	Standard Protocol	Analytical Method
Total residual oxidant	0.02	US EPA 330.3; 1978	Total Residual (titrimetric, iodometric)
Bromate	1.2	ISO 15061; 2001	Ion chromatography inductively coupled plasma- mass spectrometry
Chlorate	60	US EPA 300.1; 1997	Ion chromatography
Perchlorate	2.09	US EPA 314; 1999	Liquid chromatography ESI mass spectrometry
Dibromochloromethane	0.56	US EPA 524.2; 1995	Capillary column gas chromatography/mass spectrometry
Dichlorobromomethane	0.55		
Bromoform	0.61		
Chloroform	0.99		
Monochloroacetic acid	0.04	US EPA 552.2; 1995	Liquid-liquid extraction derivatization and gas chromatography with electron capture detection
Dichloroacetic acid	0.02		
Trichloroacetic acid	0.01		
Monobromoacetic acid	0.01		
Dibromoacetic acid	0.01		
Tribromoacetic acid	0.02		
Bromochloroacetic acid	0.09		
Dibromochloroacetic acid	0.02		
Dichlorobromoacetic acid	0.03		
Chloropicrin	0.06		
Dibromoacetone	0.06	US EPA 551.1; 1995	Liquid-liquid extraction and gas chromatography with electron capture detection
Monobromoacetone	0.08		
2,4,6-Tribromophenol	0.3	US EPA 528; 2000	Solid phase extraction and capillary column gas chromatography/mass spectrometry
1,2,3-Trichloropropane	0.73	US EPA 524.2; 1995	Capillary column gas chromatography/mass spectrometry
Thiosulfate	500	ISO 10636; 1994	Photography-processing chemicals

4 THE USE OF THE ACTIVE SUBSTANCE (G9: 4.2.6)

4.1 The manner of application

Ozone is defined as Active Substance (AS) in the BlueZone™ BWMS. When the ozone reacts with bromide ion in ballast water, the TRO, composed of hypobromous acid (HOBr) and hypobromite ion (OBr⁻), is produced.

In the BlueZone™ BWMS, the TRO concentration is automatically controlled by flow rate of injected ozone. During the ballasting process, the micro-sized ozone bubbles make the contact area between the seawater and ozone gas increase.

The neutralization module of the BlueZone™ BWMS is designed to discharge ballast water when the TRO value is less than MADCL. Thiosulfate solution is injected into the deballasting pipe to neutralize the remaining TRO. The injection rate of thiosulfate solution is controlled to maintain the concentration of TRO below MADCL, 0.2 mg/L TRO as Cl₂.

There is no harmful effect on crew because ozone and a neutralizer are directly injected into the pipe. Therefore, crew cannot be exposed to AS and RC contained in treated water. Since

treated water is stored in the ballast water tank, there is no chance for crew to expose to AS and RC contained in treated water during the voyage. Furthermore, the operating system of the BlueZone™ BWMS is designed to minimize malfunction by simplifying mechanical operations.

For more details, please refer to section 3.1, Description of the BlueZone™ BWMS, and section 3.3, Identification of Active Substances or Preparations.

For the operation and safety manual of the BlueZone™ BWMS, the instructions are provided. Also, a TRO sensor, an ozone destructor, and an ozone/oxygen detector are installed for safety. Operators, who take samples from ballast water or clean ballast tanks, are likely to be exposed to AS or RC. As recommended in the operation and safety manual, therefore, operators must wear personal protective equipment such as safety gloves and clothing, goggles and a full mask with an active carbon filter. If the skin and eyes of an operator or crew are exposed to AS or RC, operators have to rinse them with fresh water immediately. In connection with the risk assessment, the manual is considered to avoid uncontrolled or emergency situations in a safe manner.

For more details, please refer to appendix XII, Operation and safety manuals.

4.2 TRO control test results

TRO control performance of the BlueZone™ BWMS is shown in table 4.1 associated with test condition as seawater, brackish water and fresh water. TRO control of the BlueZone™ BWMS is done automatically with injection of ozone at ballasting. No neutralization was done given the discharge water TRO was < 0.2 ppm.

Table 4.1: TRO control test results (Data from appendix XIII, logged data from test cycles)

Salinity	Test date	TRO concentration (mg/L as Cl ₂)	
		Day 0	Day 5
Seawater (33 PSU)	17 Jul. 2013	2.33 ± 0.11	0.00
	24 Jul. 2013	2.23 ± 0.15	0.00
	28 Aug. 2013	2.34 ± 0.20	0.00
	4 Sep. 2013	2.37 ± 0.12	0.00
	11 Sep. 2013	2.30 ± 0.10	0.00
Brackish water (21 PSU)	12 Jun. 2013	2.06 ± 0.15	0.00
	26 Jun. 2013	2.02 ± 0.08	0.01
	25 Sep. 2013	2.29 ± 0.18	0.03
	11 Oct. 2013	2.31 ± 0.10	0.00
	23 Oct. 2013	2.36 ± 0.18	0.00
Fresh water (< 3 PSU)	11 Dec. 2013	2.21 ± 0.18	0.06

4.3 System operation limit

According to the Methodology (BWM.2/Circ.13/Rev.1), fresh water tests should be conducted and the applicable salinity range of water for the BlueZone™ BWMS should be down to fresh water condition (< 3 PSU). The salinity of water used in this test was 2.74 PSU (table 2.1).

The results from the biological efficacy test, chemical analysis, and aquatic ecotoxicity test at fresh water condition (< 3 PSU) satisfied both Guidelines (G8) and Procedure (G9). The biological efficacy test results met the performance standard described in regulation D-2 of the BWM Convention.

The analytical results for Relevant Chemicals showed that the concentrations of most RCs from the treated fresh water (< 3 PSU) were similar to those from higher salinities (21 and 33 PSU). Similarly, no significant toxicity was shown in the treated water at fresh water condition (< 3 PSU) after neutralization at day 0, day 1 and day 5.

Further assessment of ecological risk showed that PECs modelled using chemical data at 2.7 PSU were always lower than PNEC indicating that negligible risk is posed by the fresh water treated by the BlueZone™ BWMS.

5 RISK CHARACTERIZATION – HUMAN HEALTH

5.1 Hazard Identification

Human Exposure Scenario

The possible receptors here can be (1) occupational, the ship crew and/or port State workers for the operation and maintenance of the BWMS (the workers, briefly), and (2) general public, general human populations who can be exposed to the chemicals of concern (COCs) via the environment where treated ballast water is discharged, which may occur through consumption of seafood and swimming in the surrounding area.

Different exposure scenarios should be developed for each receptor group. All human receptors can be exposed to the COCs via ingestion or dermal as well as inhalation route. Depending on the scenario developed, the importance of each exposure route can be varied.

The operation and maintenance may include the usual operation of the system during ballasting and deballasting, cleaning work, repairing work and all other maintenance processes. Since the worker should wear suitable protective clothing, gloves and shoes, the possibility for the exposure of COCs in the water treated by the BWMS to workers will be very low. To assess the potential risk under worst-case situation, it is assumed that the workers do not wear protective clothing and gloves.

The BlueZone™ BWMS is a closed system, so it is very unlikely that the worker/operator is exposed to the COCs vaporized from a pipeline or ballast tank. However, the maximum level of COCs was estimated and used for the risk assessment of both occupational and public exposure.

Regarding the workers or ship crew who have the greatest potential for exposure to COCs, they can be exposed when an accidental event (spillage, leakage, etc.) occurs. The most important exposure scenarios are:

- .1 ballast water sampling;
- .2 periodic ballast tanks cleaning;
- .3 ballast tank inspections; and
- .4 normal working on the deck (not related to BWMS work).

The possible exposure scenario for the general public is the consumption of seafood and swimming activity in the surrounding area where the ballast water is discharged.

Regarding the general public population, the most important exposure scenarios are:

- .1 swimming in the sea where ballast water is discharging; and
- .2 consumption of seafood exposed to the discharged ballast water.

The representative uptake routes of chemicals including ingestion, dermal absorption and inhalation should be considered for each exposure scenario. Then all the feasible uptake routes were selected to calculate the exposure amount for each scenario.

Chemicals of concern

The chemicals of concern (COCs) in water samples treated by the BlueZone™ BWMS were analysed at day 0, day 1 and day 5 in seawater, brackish water and fresh water (shown in table 1.1 of appendix VI). Among RCs, concentrations of 15 chemicals were higher in the treated water than untreated water in seawater, brackish water or fresh water. Those chemicals were assessed for human health risk related to the maintenance and discharge of ballast water treated by the BlueZone™ BWMS (table 5.1).

In this human health risk assessment, the different chemical data were used for occupational and general public population, considering the different exposure conditions. For occupational exposure, maximum concentration among all treated water samples regardless of sampling time (day 0, day 1 or day 5) was used and maximum PEC estimated by MAMPEC-BW (version 3.0) model was used for public exposure to assess risks under worst-case scenario.

5.2 Exposure assessment

The process of exposure assessment includes the development of human exposure algorithms for all possible receptor groups. Under each exposure scenario, the most reliable information for each exposure factor was referred from the literature and used to quantify the exposure of COCs.

Occupational and general public exposures to each COCs were estimated under various scenarios and the exposure amount to ship crew is shown in table 5.1 while those of the general public in table 5.2.

Table 5.1: Exposure amount to ship crew

Substance	Sampling		Cleaning tank		Tank inspection	Normal work	Worker total ADD
	Inhalation	Dermal	Inhalation	Dermal	Inhalation	Inhalation	
Bromate	4.8.E-19	6.1.E-06	4.3.E-20	6.1.E-06	3.9.E-23	1.9.E-22	1.2.E-05
Dibromochloromethane	4.2.E-04	6.1.E-07	3.7.E-05	6.1.E-07	3.4.E-08	1.7.E-07	4.6.E-04
Dichlorobromomethane	1.5.E-08	1.0.E-06	1.3.E-09	1.0.E-06	1.2.E-12	5.8.E-12	2.0.E-06
Bromoform	5.3.E-03	1.4.E-05	4.7.E-04	1.4.E-05	4.2.E-07	2.1.E-06	5.8.E-03
Chloroform	6.1.E-03	2.4.E-06	5.4.E-04	2.4.E-06	4.9.E-07	2.4.E-06	6.7.E-03
Dichloroacetic acid	4.7.E-15	8.1.E-08	4.2.E-16	8.1.E-08	3.7.E-19	1.9.E-18	1.6.E-07
Monobromoacetic acid	2.5.E-10	5.5.E-08	2.2.E-11	5.5.E-08	2.0.E-14	1.0.E-13	1.1.E-07
Dibromoacetic acid	1.4.E-08	4.7.E-06	1.3.E-09	4.7.E-06	1.2.E-12	5.8.E-12	9.4.E-06
Tribromoacetic acid	1.9.E-09	8.0.E-07	1.7.E-10	8.0.E-07	1.5.E-13	7.5.E-13	1.6.E-06
Bromochloroacetic acid	7.5.E-09	6.6.E-07	6.7.E-10	6.6.E-07	6.0.E-13	3.0.E-12	1.3.E-06
Dibromochloroacetic acid	8.4.E-14	4.7.E-06	7.5.E-15	4.7.E-06	6.7.E-18	3.4.E-17	9.4.E-06
Dichlorobromoacetic acid	8.6.E-15	1.6.E-07	7.6.E-16	1.6.E-07	6.9.E-19	3.4.E-18	3.2.E-07
Chloropicrin	4.2.E-09	3.0.E-07	3.7.E-10	3.0.E-07	3.3.E-13	1.7.E-12	6.0.E-07
Monobromoacetonitrile	1.0.E-11	3.6.E-06	9.0.E-13	3.6.E-06	8.1.E-16	4.0.E-15	7.2.E-06
Dibromoacetonitrile	2.9.E-05	1.0.E-04	2.6.E-06	1.0.E-04	2.3.E-09	1.2.E-08	2.4.E-04

Table 5.2: Exposure amount to the general public

Substances	Swimming RCR			Consumption of seafood	Public total ADD
	Inhalation	Dermal	Chemical swallowed	Eating fish	
Bromate	3.9.E-23	2.6.E-06	3.3.E-07	NC	2.9.E-06
Dibromochloromethane	2.6.E-09	2.0.E-08	2.6.E-09	1.2.E-07	1.5.E-07
Dichlorobromomethane	8.8.E-14	3.1.E-08	4.1.E-09	1.5.E-07	1.9.E-07
Bromoform	4.5.E-08	6.3.E-07	8.1.E-08	1.6.E-06	2.4.E-06
Chloroform	3.2.E-08	6.6.E-08	8.6.E-09	1.3.E-07	2.4.E-07
Dichloroacetic acid	9.5.E-20	8.6.E-09	1.1.E-09	1.8.E-09	1.1.E-08
Monobromoacetic acid	5.2.E-15	6.0.E-09	7.7.E-10	1.3.E-08	2.0.E-08
Dibromoacetic acid	3.0.E-13	5.1.E-07	6.6.E-08	6.0.E-08	6.4.E-07
Tribromoacetic acid	3.9.E-14	8.7.E-08	1.1.E-08	3.8.E-08	1.4.E-07
Bromochloroacetic acid	1.6.E-13	7.3.E-08	9.3.E-09	1.6.E-07	2.4.E-07
Dibromochloroacetic acid	1.8.E-18	5.1.E-07	6.6.E-08	1.1.E-06	1.7.E-06
Dichlorobromoacetic acid	1.8.E-19	1.7.E-08	2.2.E-09	NC	1.9.E-08
Chloropicrin	8.7.E-14	3.2.E-08	4.2.E-09	1.8.E-07	2.1.E-07
Monobromoacetonitrile	2.1.E-16	3.9.E-07	5.1.E-08	4.3.E-07	8.7.E-07
Dibromoacetonitrile	6.1.E-10	1.1.E-05	1.4.E-06	2.3.E-05	3.6.E-05

* NC: Not calculated.

5.3 Effect assessment

Effect assessment estimated potential risks to receptors at exposure levels of interest. During the effect assessment process, the toxicity data for COCs are compiled by reviewing a variety of toxicological data from reliable literature and databases. Detailed toxicity information is described in table 5.3.

Table 5.3: Results of the effect assessment of COCs

Substances	^a NOAEL (mg/kg/d)	DNEL _{inh-8h-la} (mg/m ³)	DNEL _{inh-24h-ba} (mg/m ³)	DNEL _{inh-2.5h-la} (mg/m ³)	DNEL _{oral} (mg/kg/d)
Bromate	1.1	5.5.E-03	3.8.E-02	1.9.E-02	1.2.E-01
Dibromochloromethane	21.4	1.1.E-01	7.4.E-01	3.7.E-01	2.4.E+00
Dichlorobromomethane	17.9	9.0.E-02	6.2.E-01	3.1.E-01	2.0.E+00
Bromoform	17.9	9.0.E-02	6.2.E-01	3.1.E-01	2.0.E+00
Chloroform	15	2.1.E-01	5.2.E-01	2.6.E-01	1.7.E+00
Monochloroacetic acid	12.5	1.8.E-01	4.3.E-01	2.2.E-01	1.4.E+00
Dichloroacetic acid	2	1.0.E-02	7.0.E-02	3.5.E-02	2.2.E-01
Trichloroacetic acid	2	1.0.E-02	7.0.E-02	3.5.E-02	2.2.E-01
Dibromoacetic acid	2	1.0.E-02	7.0.E-02	3.5.E-02	2.2.E-01
Bromochloroacetic acid	13	6.5.E-02	4.5.E-01	2.3.E-01	1.4.E+00
Dibromochloroacetic acid	2	1.0.E-02	7.0.E-02	3.5.E-02	2.2.E-01
Dichlorobromoacetic acid	2	1.0.E-02	7.0.E-02	3.5.E-02	2.2.E-01
Chloropicrin	8	4.0.E-02	2.8.E-01	1.4.E-01	8.9.E-01
Monobromoacetonitrile	11.3	5.7.E-02	3.9.E-01	2.0.E-01	1.3.E+00
Dibromoacetonitrile	11.3	5.7.E-02	3.9.E-01	2.0.E-01	1.3.E+00

^a Toxicity (NOAEL) data for these 6 chemicals were not available, so the AFs for similar compounds were used instead.

5.4 Risk characterization

Finally, the risk characterization process is a comparison of the exposure level to various Derived No Effect Levels (DNELs). The RCR is calculated according to the following formula:

$$RCR = Exposure / DNEL$$

If the RCR is below 1, the exposure is deemed to be safe. However, risk is regarded to be controlled when the estimated exposure levels do not exceed the Derived No Effect Levels (DNEL), that is even if the $RCR \geq 1$.

The risk characterization ratios for human receptors including occupational, such as operator and ship crew, and the general public were all below the acceptable risk level (tables 7.1 and 7.2), which means that the potential risk of COCs related to the BlueZone™ BWMS will be low enough even under conservative assumptions for the exposure conditions. The detail for the procedure of risk characterization estimation of COCs is shown in appendix VI.

No occupational or public exposure (ADD, average daily dose) to COCs exceeded DNEL in this assessment (table 5.3). RCRs for the aggregated exposure in all scenarios were also all less than 1 indicating that the BlueZone™ BWMS may pose negligible risk to both workers and the general public.

6 RISK CHARACTERIZATION – ENVIRONMENT

6.1 Screening for Persistence, Bioaccumulation, and Toxicity (G9: 5.1)

Based on an evaluation of the available data presented in the table 6.2, none of the substances meet all three criteria (table 6.1) to be considered as PBT substances.

Table 6.1: Standard criteria determining the PBT chemical

Criterion	PBT criteria
Persistence	Half-life > 60 days in marine water, or > 40 days in fresh water, or > 180 days in marine sediment, or > 120 days in freshwater sediment
Bioaccumulation	BCF > 2,000 or Log K _{ow} ≥ 3
Toxicity	Chronic NOEC < 0.01 mg/L

Table 6.2: PBT criteria evaluation

Chemical	Persistence (Yes/No)	Bioaccumulation (Yes/No)	Toxicity (Yes/No)
Bromate	No SW: 12 hours	No BCF = 3.2 Log K _{ow} = -4.6	No NOEC = 8 mg/L/7d (algae)
Chlorate	No Water: 15 days	No BCF = 3.2 Log K _{ow} = -4.63	No PBT profiler
Perchlorate	No Water: 15 days	No BCF = 3.2 Log K _{ow} = -4.63	No NOEC = 0.75 mg/L/10d (fish)
Dibromochloromethane	No Water: 38 days	No BCF = 27.64 Log K _{ow} = 2.17	No NOEC = 3.2 mg/L/21 day (fish)
Dichlorobromomethane	No FW: 5 days	No BCF = 7 Log K _{ow} = 0.22	No LC ₅₀ = 34 mg/L (fish)
Bromoform	No FW: 7.1 days	No BCF = 14 Log K _{ow} = 2.4	No Lowest NOEC = 8.5 mg/L (fish)
Chloroform	No FW: 4.4 days	No BCF = 2.9-10.35 Log K _{ow} = 1.97	No Lowest NOEC = 1.5 mg/L (fish)
Monochloroacetic acid	No FW: 14 days	No Log K _{ow} = 0.22	No Lowest NOEC = 0.13 mg/L (algae)
Dichloroacetic acid	No FW: 4 days	No Log K _{ow} = 0.92	No EC ₃₀ = 1485 mg/L (algae)
Trichloroacetic acid	No FW: 40 days	No BCF = 0.1~1.7	No Lowest NOEC = 100 mg/L (algae)
Monobromoacetic acid	No Water: 8.7 days	No BCF = 3.2 Log K _{ow} = 0.41	No EC ₅₀ = 1.6 mg/L/21 days (crustacean)
Dibromoacetic acid	No Water: 15 days	No BCF = 0.17 Log K _{ow} = 0.70	No LC ₅₀ = 69 mg/L/4 days (fish)
Tribromoacetic acid	No Water: 15 days	No BCF = 0.63 Log K _{ow} = 1.71	No LC ₅₀ = 68.7 mg/L/2 days (crustacean)
Bromochloroacetic acid	No Water: 15 days	No BCF = 3.2 Log K _{ow} = 0.61	No LC ₅₀ = 6.9 mg/L/4 days (fish)

Chemical	Persistence (Yes/No)	Bioaccumulation (Yes/No)	Toxicity (Yes/No)
Dibromochloroacetic acid	No Activated sludge: 100%(aerobic), 28 days	No Log K _{ow} = 1.62	No PBT profiler
Dichlorobromoacetic acid	No Water: 37.5 days	No BCF = 1 Log K _{ow} = 1.53	No LC ₅₀ = 63.8 mg/L/ 2 days (crustacean)
Chloropicrin	No Water: 60 days	No Log K _{ow} = -0.25	No NOEC = 0.22 mg/L (fish)
Monobromoacetonitrile	No Water: 15 days	No Log K _{ow} = 0.2	No PBT profiler
Dibromoacetonitrile	No Water: 38 days	No BCF= 3 Log K _{ow} = 0.47	No LC ₅₀ = 0.55 mg/L/ 4 days (fish)
2,4,6-Tribromophenol	No FW: 1.21 days	No BCF = 83-513 Log K _{ow} = 3.89	No Lowest NOEC = 0.10 mg/L (crustacean)
1,2,3-Trichloropropane	No Water: 37.5 days	No BCF= 59.33 Log K _{ow} = 3.17	No PBT profiler
Sodium thiosulfate	No Biodegrades fast	No BCF = 3.162 Log K _{ow} = -4.53	No NOEC: 720 mg/L/ 2 days (algae)

6.1.1 Persistence (G9: 5.1.1.1)

No new information, please refer to section 6.1.1 of the annex to document MEPC 65/2/5.

6.1.2 Bioaccumulation (G9: 5.1.1.2)

No new information, please refer to section 6.1.2 of the annex to document MEPC 65/2/5.

6.1.3 Toxicity tests (G9: 5.1.1.3)

No new information, please refer to section 6.1.3 of the annex to document MEPC 65/2/5.

6.2 Evaluation of the treated ballast water (G9: 5.2)

This section is intended to evaluate the effects of Preparations and their components on organisms and the environment when released with treated ballast water or accidentally during the process.

The effects of treated water by the BlueZone™ BWMS on various marine organisms were evaluated in various acute and chronic ecotoxicity tests using seawater (33 PSU), brackish water (21 PSU) and fresh water (< 3 PSU).

WET tests associated with the BlueZone™ BWMS treated seawater covering multiple test species indicated no acute and chronic ecotoxicity for any test organisms at discharge (day 0, day 1 and day 5) as tested compared to control water. Even full strength effluent (100%) did not cause any significant deleterious effects on any of the test species in both acute and chronic tests. Consequently, deballasting water is expected to be non-toxic to aquatic organisms as well as to the marine and freshwater environment in general. The actual NOEC for BlueZone™ BWMS treated seawater was not measurable; the statistically determined NOEC was 100%.

Table 6.3 summarizes acute aquatic ecotoxicity data on three types of water associated with the BlueZone™ BWMS and table 6.4 summarizes chronic aquatic ecotoxicity data on the same types of water. WET testing was performed by NeoEnBiz Co. Acute aquatic ecotoxicity tests were conducted with 3 taxonomic groups including microalgae, rotifer and fish on three types of water samples as full-strength seawater (33 PSU), brackish water (21 PSU) and fresh water (< 3 PSU). Also, chronic aquatic ecotoxicity tests were conducted with rotifer and fish on three water types of samples.

The samples for WET testing at day 0 were collected directly from the sampling ports of treatment line with neutralization applied. At day 1, water samples were taken from the pipes installed on the side of the treated water tank, and neutralized. Day 5 samples were taken from sampling ports during discharge, which has been through neutralization within the BWMS unit. All samples for WET testing were stored in proper sample containers at 4°C and transported to the designated laboratory within 12 hours of collection (please refer to appendix IV, annex 1, sample transportation log sheet).

WET tests of the samples occurred within the time specified under standard laboratory procedures. All tests were performed according to laboratory protocols based on internationally recognized ISO, ASTM and/or US EPA standards. For the validation of test results, all performance criteria were checked according to OECD and other standard protocols. Especially for WET tests with algae, the following three criteria were validated and the detailed results are shown in section 2.2.2 of appendix IV:

- .1 the biomass should increase exponentially by a factor of at least 16 within the 72-hour test period. This corresponds to a specific growth rate of 0.92 d⁻¹;
- .2 the mean coefficient of variation for section-by-section specific growth rates (days 0-1, 1-2 and 2-3, for 72-hour tests) must not exceed 35% (OECD 201); and
- .3 the coefficient of variation of average specific growth rates in the replicates during the whole test period must not exceed 10% (OECD 201).

Table 6.3: The results of acute toxicity tests on day 0, day 1 and day 5 samples using various marine and freshwater organisms exposed to treated water after neutralization associated with the BlueZone™ BWMS

Salinity	Species group	Species	Deballasting day	Endpoint			Remark (test protocol)	
				NOEC (%)	LOEC (%)	LC ₅₀ or EC ₅₀ (%)		
Seawater (33 PSU)	Algae	<i>Skeletonema costatum</i>	Day 0	100	> 100	> 100	ASTM E1218/ OECD201	Population growth inhibition (72 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Rotifer	<i>Brachionus plicatilis</i>	Day 0	100	> 100	> 100	ASTM E1440	Mortality (24 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		

Brackish water (21 PSU)	Fish	<i>Cyprinodon variegates</i>	Day 0	100	> 100	> 100	US EPA 821/R02/012	Mortality (96 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Algae	<i>Skeletonema costatum</i>	Day 0	100	> 100	> 100	ASTM E1218/ OECD201	Population growth inhibition (72 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Rotifer	<i>Brachionus plicatilis</i>	Day 0	100	> 100	> 100	ASTM E1440	Mortality (24 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
Fresh water (< 3 PSU)	Fish	<i>Cyprinodon variegates</i>	Day 0	100	> 100	> 100	US EPA 821/R02/012	Mortality (96 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Algae	<i>Pseudokirchneriella subcapitata</i>	Day 0	100	> 100	> 100	ASTM E1218/ OECD201	Population growth inhibition (72 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Rotifer	<i>Brachionus calyciflorus</i>	Day 0	100	> 100	> 100	ASTM E1440	Mortality (24 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Fish	<i>Oryzias latipes</i>	Day 0	100	> 100	> 100	US EPA 821/R02/012	Mortality (96 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		

Chronic aquatic ecotoxicity tests on three types of water associated with the BlueZone™ BWMS were conducted. The following table 6.4 summarizes chronic aquatic ecotoxicity test results for the samples collected at day 0, day 1 and day 5 for seawater (33 PSU), brackish water (21 PSU) and fresh water (< 3 PSU) associated with the BlueZone™ BWMS.

Table 6.4: The results of chronic ecotoxicity tests on day 0, day 1 and day 5 samples using various marine and freshwater organisms exposed to treated water after neutralization associated with the BlueZone™ BWMS

Salinity	Species group	Species	Deballasting day	Endpoint			Remark (test protocol)	
				NOEC (%)	LOEC (%)	LC ₅₀ or EC ₅₀ (%)		
Seawater (33 PSU)	Rotifer	<i>Brachionus plicatilis</i>	Day 0	100	> 100	> 100	Janssen et al., 1994	Population growth rate (96 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Fish	<i>Cyprinodon variegates</i>	Day 0	100	> 100	> 100	US EPA 821/R02/014	Growth rate (7 days)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
Brackish water (21 PSU)	Rotifer	<i>Brachionus plicatilis</i>	Day 0	100	> 100	> 100	Janssen et al., 1994	Population growth rate (96 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Fish	<i>Cyprinodon variegates</i>	Day 0	100	> 100	> 100	US EPA 821/R02/014	Growth rate (7 days)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		

Salinity	Species group	Species	Deballasting day	Endpoint			Remark (test protocol)	
				NOEC (%)	LOEC (%)	LC ₅₀ or EC ₅₀ (%)		
Fresh water (< 3 PSU)	Rotifer	<i>Brachionus calyciflorus</i>	Day 0	100	> 100	> 100	Janssen et al., 1994	Population growth rate (96 hrs)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		
	Fish	<i>Oryzias latipes</i>	Day 0	100	> 100	> 100	US EPA 821/R02/014	growth rate (7 days)
			Day 1	100	> 100	> 100		
			Day 5	100	> 100	> 100		

6.2.1 Determination of holding time

The neutralization module of the BlueZone™ BWMS will be operated to neutralize the remaining TRO during deballasting. So there is no holding time for the treated water to discharge.

6.3 Risk characterization and analysis

6.3.1 Prediction of discharge and environmental concentrations

The MAMPEC-BW model version 3.0 was used to calculate the PEC of Relevant Chemicals in the GESAMP-BWWG Model Harbour. It can be used in modified form, to calculate the concentrations constantly released into the water by other processes; for example ballast water treatment. The model's applicability to any chemical substance made it a useful tool for environmental impact studies.

PEC for all Relevant Chemicals under the BlueZone™ BWMS was calculated with highest concentration (maximum discharge) of any chemical analysis result among day 0, day 1 and day 5 regardless of control and treated water and both before and after neutralization. PEC was also modelled on seawater and brackish water, respectively (table 6.5).

Table 6.5: Results of PECs on ballast water discharged in the GESAMP-BWWG Model Harbour

Chemicals	Seawater (33 PSU)		Brackish water (21 PSU)		Fresh water (< 3 PSU)	
	Maximum discharge conc. (mg/L)	PEC (µg/L)	Maximum discharge conc. (mg/L)	PEC (µg/L)	Maximum discharge conc. (mg/L)	PEC (µg/L)
Bromate (sodium)	2.39E-02	6.27E-01	3.98E-02	1.05E+00	1.59E-02	4.17E+00
Chlorate	6.00E-02	1.62E+00	6.00E-02	1.62E+00	6.00E-02	1.62E+00
Perchlorate	2.09E-03	5.63E-02	2.09E-03	5.63E-02	2.09E-03	5.63E-02
Dibromochloromethane	2.02E-03	1.62E-02	3.99E-03	3.20E-02	3.67E-03	2.95E-02
Dichlorobromomethane	5.50E-04	4.26E-03	4.05E-03	3.14E-02	6.54E-03	5.07E-02
Bromoform	9.28E-02	1.01E+00	6.56E-02	7.12E-01	8.97E-02	9.74E-01
Chloroform	9.90E-04	6.68E-03	9.90E-04	6.68E-03	1.58E-02	1.07E-01
Monochloroacetic acid	6.10E-04	1.64E-02	1.05E-03	2.83E-02	8.00E-05	2.15E-03
Dichloroacetic acid	2.00E-05	5.21E-04	2.00E-05	5.21E-04	5.30E-04	1.38E-02
Trichloroacetic acid	1.00E-05	2.69E-04	1.00E-05	2.69E-04	1.04E-03	2.80E-02

Chemicals	Seawater (33 PSU)		Brackish water (21 PSU)		Fresh water (< 3 PSU)	
	Maximum discharge conc. (mg/L)	PEC (µg/L)	Maximum discharge conc. (mg/L)	PEC (µg/L)	Maximum discharge conc. (mg/L)	PEC (µg/L)
Monobromoacetic acid	1.00E-05	2.69E-04	1.00E-05	2.69E-04	3.60E-04	9.67E-03
Dibromoacetic acid	2.05E-02	2.69E-04	3.06E-02	8.24E-01	1.21E-03	3.26E-02
Tribromoacetic acid	3.33E-03	8.97E-02	5.23E-03	1.41E-01	2.92E-03	7.86E-02
Bromochloroacetic acid	1.59E-03	4.28E-02	2.64E-03	4.28E-02	4.33E-03	1.17E-01
Dibromochloroacetic acid	1.63E-02	2.69E-04	3.06E-02	7.25E-01	2.05E-03	5.52E-02
Dichlorobromoacetic acid	3.00E-05	8.08E-04	1.03E-03	2.77E-02	7.50E-04	2.02E-02
Chloropicrin	6.00E-05	1.62E-03	1.93E-03	5.20E-02	1.05E-03	2.83E-02
Monobromoacetonitrile	2.35E-02	6.34E-01	4.41E-03	1.19E-01	7.50E-04	2.02E-02
Dibromoacetonitrile	6.74E-01	1.81E+01	5.76E-02	1.55E+00	7.36E-03	1.98E-01
2,4,6-Tribromophenol	3.00E-04	8.07E-03	3.00E-04	8.07E-03	3.00E-04	8.07E-03
1,2,3-Trichloropropane	7.30E-04	7.55E-03	7.30E-04	7.55E-03	7.30E-04	7.55E-03

6.3.2 Effects assessment

The data for the substances associated with use of the BlueZone™ BWMS indicate that there is a low potential for bioaccumulation, sediment adsorption and persistence in the aquatic environment. No effects or risks in the form of secondary (food chain) poisoning or to sediment species are anticipated. As such, aquatic toxicity presents the only likely potential risk for aquatic organisms.

Whole effluent toxicity testing (acute and chronic endpoints) of treated water both before and after the neutralization process suggests no apparent toxicity for all species and endpoints tested (L(E)C₅₀ and/or NOEC values of ≥ 100% for each ballast water sample). In light of these results, although aquatic toxicity is identified as having the highest potential for risk to aquatic organisms, WET testing results suggest that potential risk is low.

6.3.3 Effects on aquatic organisms

Predicted No-Effect Concentrations (PNEC) values were calculated using the aquatic toxicity data set endpoints and the appropriate assessment factor. A thorough literature review of available PNEC values for the chemicals was also conducted and the data are presented in table 6.6.

Table 6.6: Predicted No-Effect Concentration (PNEC) for chemicals detected from treated ballast water at discharge

Chemical	**Toxicity value (mg/L)	Assessment Factor	PNEC (µg/L)	Comment(s)
Bromate	8	100	80	Lowest chronic toxicity value
Chlorate	-	-	1150	*From ECHA
Perchlorate	-	-	100	*From ECHA
Dibromochloromethane	34	1000	34	Lowest acute toxicity value
Dichlorobromomethane	67.4	1000	67.4	Lowest acute toxicity value

Chemical	**Toxicity value (mg/L)	Assessment Factor	PNEC (µg/L)	Comment(s)
Bromoform	8.5	100	85	Lowest chronic toxicity value
Chloroform	-	-	15	*From ECHA
Monochloroacetic acid	8.5	100	85	Lowest chronic toxicity value
Dichloroacetic acid	23	1000	23	Lowest acute toxicity value
Trichloroacetic acid	100	1000	100	Lowest acute toxicity value
Monobromoacetic acid	1.4	1000	1.4	Lowest acute toxicity value
Dibromoacetic acid	69	1000	69	Lowest chronic toxicity value
Tribromoacetic acid	69	1000	69	Assumed to be the same value as that for dibromoacetic acid
Bromochloroacetic acid	69	1000	69	Assumed to be the same value as that for dibromoacetic acid
Dibromochloroacetic acid	55.6	1000	55.6	IMO 2012
Dichlorobromoacetic acid	63.8	1000	63.8	ECOSAR, 2011
Chloropicrin	0.022	10	2.2	ECOSAR, 2011
Monobromoacetonitrile	0.55	1000	0.55	Assumed to be the same value as that for dibromoacetonitrile
Dibromoacetonitrile	0.55	1000	0.55	Lowest acute toxicity value
2,4,6-Tribromophenol	0.1	100	1	Lowest chronic toxicity value
1,2,3-Triichloropropane	-	-	8.8	*From ECHA

* PNEC value directly from ECHA (European Chemicals Agency) web-database

** Toxicity values from appendix XII

6.3.4 Comparison of effect assessment with discharge toxicity

The information reviewed for degradation and bioaccumulation of the substances related to the use of the BlueZone™ BWMS suggests that potential effects from these mechanisms cannot be reasonably anticipated. The effects assessment establishes that there is potential for reaction of the Active Substances with organic matter and formation of DBPs. This has been confirmed by data from ballast water discharge samples analysed for DBPs. The presence of DBPs in disinfected water can potentially result in toxic effects to aquatic organisms. All toxicity tests on treated water neutralized with sodium thiosulfate resulted in L(E)C₅₀ and/or NOEC values ≥ 100%. Ballast water sample discharge toxicity testing results are consistent with the overall effects assessment that the potential effects are related to aquatic toxicity, rather than bioaccumulation or persistence in the environment. Further, the toxicity observed with neutralized discharge samples was not found in any one of species tested.

7 RISK ASSESMENT

7.1 Risk to safety of ship

7.1.1 Fire and explosion

Oxygen is non-combustible, but it enables and promotes combustion processes. Oxygen can cause spontaneous ignition of oil and grease. This also applies to clothing soiled by oil and grease.

An increased oxygen concentration causes a considerable increase in the combustion speed. Furthermore, technical safety characteristics such as pressure increase speeds, ignition and glow temperatures, explosion pressures and flame temperatures also change. Oxygen bonds with almost all elements. Most substances react so violently with oxygen that there is an increased fire hazard.

For more details, please refer to section 4.9 in appendix XII.

7.1.2 Storage and handling of the substances

The BlueZone™ BWMS does not require the storage of any chemicals on board, except for the sodium thiosulfate solution as a neutralizing agent. The solution is the only chemical substance that needs to be stored and handled on board. The amount of stored sodium thiosulfate solution will vary depending on the amount of treated ballast water and will be specific to each installation. Sodium thiosulfate solution is stored in epoxy coated SS 400 or stainless steel (SUS304) tanks.

A 30% solution of sodium thiosulfate will be used, which is available in most cities around the world. Tanks containing the solution will be placed on the ship by crane from a land facility. The neutralization unit will be installed in a pump room or engine room of the ship and a refilling pipe is also installed. The solution of sodium thiosulfate will be transferred from a storage tank on the ship to a feeder tank in a pump room or engine room through the refilling pipe. A level transmitter installed at the feeder tank monitors the level in the tank. If the feeder tank is empty, the neutralization unit will generate an alarm and the system will be shut down.

When handling thiosulfate solution, crew should be equipped with splash goggles, gloves and boots and self-contained breathing apparatus should be used to avoid inhalation of vapour from the solution. If crew's eyes are contaminated by the solution, the crew should wash their eyes in running water immediately and keep eyelids open. If crew's skin is exposed to the concentrated solution, the crew should gently and thoroughly wash the contaminated skin in running water with non-abrasive soap. The solution of sodium thiosulfate is not a flammable substance. Thus, there is no risk of fire due to the solution.

7.1.3 Corrosion

Full corrosion testing was carried out over a period of six months in accordance with the recommendations provided in section 3.6.9 of the Methodology (BWM.2/Circ.13/Rev.1). The results of corrosion tests with epoxy coated steel specimen show that there was no significant change of performance during the test period of corrosion resistance between the untreated and treated seawater. Also, the results of uncoated metallic specimens (316 L, titanium, copper, and brass) in the control (untreated) and treated seawater were the same. The immersion corrosion test of non-metals showed similar rates of corrosion between the untreated and treated seawater. Non-metals are three types of rubber specimens, NBR, EPDM, and VITON (FKM). From the corrosion resistance test of rubber material including NBR, EPDM and VITON, there was no difference of physical properties such as tensile strength, elongation, and hardness. Consequently, the corrosion test results show that corrosion on ballast tanks or pipes is not likely to worsen when exposed to seawater treated by the BlueZone™ BWMS.

7.2 Risk to human health

7.2.1 Health effect on humans

For this system, ozone detectors will be placed near the ozone generator and in some places where there is a possibility of a leak. If leaking ozone is detected, audible alarms ring and the system will shut down. Crew are directed to leave to a safety zone. As soon as leakage occurs, the ventilation system will automatically run. Therefore, there is little probability of exposure to any significant level harmful to the crew in the normal operation of the ozone, an Active Substance of this system.

During system operating process on ships, crew will not be exposed to ozone used in the BlueZone™ BWMS. When overhauling the ballast tank, direct contacts will occur and the exposure will be minimized by the recommended handling procedures that include personal protective equipment, gloves, goggles and, if needed, a respirator. As the main hazards of the product are caused by local irritations/corrosions at the contact site and there is no immediate concern for mutagenicity or carcinogenicity, the product can be handled safely in this application. The health risks of Relevant Chemicals posed by the BlueZone™ BWMS are assessed under various exposure scenarios. The treatment by the system has negligible adverse effects upon inhalation, dermal and/or oral exposure route, both occupational and general public (tables 7.1 and 7.2).

Table 7.1: Risk Characterization Ratios (RCR) estimated for daily occupational exposure

Substance	Sampling		Cleaning tank		Tank inspection	Normal work	Total worker RCR
	Inhalation	Dermal	Inhalation	Dermal	Inhalation	Inhalation	
Bromate	1.3E-17	1.1E-03	1.1E-18	1.1E-03	1.0E-21	5.0E-21	2.2E-03
Dibromochloromethane	5.7E-04	5.7E-06	5.0E-05	5.7E-06	4.5E-08	2.3E-07	6.3E-04
Dichlorobromomethane	2.3E-08	1.1E-05	2.1E-09	1.1E-05	1.9E-12	9.4E-12	2.2E-05
Bromoform	8.5E-03	1.6E-04	7.6E-04	1.6E-04	6.8E-07	3.4E-06	9.6E-03
Chloroform	1.2E-02	1.1E-05	1.0E-03	1.1E-05	9.4E-07	4.7E-06	1.3E-02
Dichloroacetic acid	1.1E-14	4.6E-07	9.6E-16	4.6E-07	8.6E-19	4.3E-18	9.1E-07
Monobromoacetic acid	3.6E-09	5.5E-06	3.2E-10	5.5E-06	2.9E-13	1.4E-12	1.1E-05
Dibromoacetic acid	2.1E-07	4.7E-04	1.8E-08	4.7E-04	1.7E-11	8.3E-11	9.4E-04
Tribromoacetic acid	2.7E-08	8.0E-05	2.4E-09	8.0E-05	2.1E-12	1.1E-11	1.6E-04
Bromochloroacetic acid	1.7E-08	1.0E-05	1.5E-09	1.0E-05	1.3E-12	6.6E-12	2.0E-05
Dibromochloroacetic acid	1.2E-12	4.7E-04	1.1E-13	4.7E-04	9.7E-17	4.8E-16	9.4E-04
Dichlorobromoacetic acid	1.2E-13	1.6E-05	1.1E-14	1.6E-05	9.9E-18	4.9E-17	3.2E-05
Chloropicrin	1.5E-08	7.4E-06	1.3E-09	7.4E-06	1.2E-12	6.0E-12	1.5E-05
Monobromoacetonitrile	2.6E-11	6.4E-05	2.3E-12	6.4E-05	2.1E-15	1.0E-14	1.3E-04
Dibromoacetonitrile	7.4E-05	1.8E-03	6.6E-06	1.8E-03	5.9E-09	3.0E-08	3.7E-03

Table 7.2: Risk Characterization Ratios (RCR) estimated for daily public exposure

Substances	Swimming			Consumption of seafood	Public total RCR
	Inhalation	Dermal	Chemical swallowed	Consumption of fish	
Bromate	3.2E-22	4.7E-04	6.06.E-05	NC	5.3E-04
Dibromochloromethane	1.1E-09	1.9E-07	2.39.E-08	1.16E-06	1.4E-06
Dichlorobromomethane	4.4E-14	3.5E-07	4.53.E-08	1.70E-06	2.1E-06
Bromoform	2.2E-08	7.0E-06	9.02.E-07	1.84E-05	2.6E-05
Chloroform	1.9E-08	3.1E-07	3.99.E-08	6.22E-07	9.9E-07
Dichloroacetic acid	6.8E-20	4.8E-08	6.18.E-09	9.95E-09	6.4E-08
Monobromoacetic acid	2.4E-14	6.0E-07	7.73.E-08	1.33E-06	2.0E-06
Dibromoacetic acid	1.4E-12	5.1E-05	6.58.E-06	6.01E-06	6.4E-05
Tribromoacetic acid	1.8E-13	8.7E-06	1.13.E-06	3.81E-06	1.4E-05
Bromochloroacetic acid	1.1E-13	1.1E-06	1.44.E-07	2.47E-06	3.7E-06
Dibromochloroacetic acid	7.9E-18	5.1E-05	6.58.E-06	1.12E-04	1.7E-04
Dichlorobromoacetic acid	8.1E-19	1.7E-06	2.21.E-07	NC	1.9E-06
Chloropicrin	9.8E-14	8.1E-07	1.04.E-07	4.46E-06	5.4E-06
Monobromoacetonitrile	1.7E-16	7.0E-06	8.97.E-07	7.61E-06	1.5E-05
Dibromoacetonitrile	4.8E-10	2.0E-04	2.56.E-05	4.06E-04	6.3E-04

NC: Not calculated.

7.2.2 Human exposure scenario

The possible receptors here can be (1) occupational, the crew and/or port State workers for the operation and maintenance of the BWMS (the workers, briefly), and (2) general public, general human populations who can be exposed to the chemicals of concern (COCs) via the environment where treated ballast water is discharged, which may occur through consumption of seafood and swimming in the surrounding area.

Different possible scenarios in the case of exposure should be developed for each receptor group. All human receptors can be exposed to the COCs via ingestion or dermal absorption as well as inhalation. Depending on the developed scenarios, the importance of each exposure route can be varied.

The operation and maintenance may include the usual operation during ballasting and deballasting, cleaning work, repairing work and all other maintenance processes. Since the operator should wear suitable protective clothing, gloves and shoes, the possibility of the exposure for operators to COCs in the water treated by the BWMS will be very low. To assess the potential risk under the worst-case scenario, it is assumed that the operators do not wear protective clothing and gloves.

It is unlikely that the operators will be exposed to the COCs vaporized from a pipeline or ballast tank because of the closed system of the BlueZone™ BWMS. However, the maximum level of COCs was estimated and used for the risk assessment of both occupational and public exposure.

No occupational or public exposure (average daily dose) to COCs exceeded DNEL in this assessment (table 5.3). RCRs of the aggregated exposure for all scenarios were also all less than 1 indicating that the BlueZone™ BWMS may pose negligible risk to both workers and the general public.

7.3 Risk to aquatic environment

Data for the chemicals used for the BlueZone™ BWMS indicate that there is a low potential for bioaccumulation, sediment adsorption and persistence in the aquatic environment. No effects or risks in the form of secondary (food chain) poisoning or to sediment species are anticipated. As such, ecotoxicity presents the only likely potential risk for aquatic organisms.

Therefore, WET testing of the treated ballast discharge indicates that unacceptable risks to the aquatic environment are not expected from the BlueZone™ BWMS. Ecotoxicity test results revealed no measurable levels of potentially toxic substances and no significant acute and chronic effects of the d-ballasting samples on aquatic organisms. No apparent environmental risks could therefore be identified.

Most of the ecotoxicity data from the literature show that the remaining levels of Active Substance and potential Relevant Chemicals are not considered toxic to most aquatic organisms. In conclusion, no test results found any measurable level of potentially toxic substances and any acute or chronic effect on aquatic organisms from the deballasting water.

Table 7.3: PEC/PNEC ratios on Relevant Chemicals in GESAMP-BWWG Model Harbour

Chemicals	Seawater (33 PSU)			Brackish water (21 PSU)			Fresh water (<3 PSU)		
	PEC (µg/L)	PNEC (µg/L)	PEC/ PNEC	PEC (µg/L)	PNEC (µg/L)	PEC/ PNEC	PEC (µg/L)	PNEC (µg/L)	PEC/ PNEC
Bromate (Sodium)	6.27E-01	80	7.84E-03	1.05E+00	80	1.31E-02	4.17E+00	80	5.21E-02
Chlorate	1.62E+00	1150	1.41E-03	1.62E+00	1150	1.41E-03	1.62E+00	1150	1.41E-03
Perchlorate	5.63E-02	100	5.63E-04	5.63E-02	100	5.63E-04	5.63E-02	100	5.63E-04
Dibromochloromethane	1.62E-02	34	4.76E-04	3.20E-02	34	9.41E-04	2.95E-02	34	8.68E-04
Dichlorobromomethane	4.26E-03	67.4	6.32E-05	3.14E-02	67.4	4.66E-04	5.07E-02	67.4	7.52E-04
Bromoform	1.01E+00	85	1.19E-02	7.12E-01	85	8.38E-03	9.74E-01	85	1.15E-02
Chloroform	6.68E-03	15	4.45E-04	6.68E-03	15	4.45E-04	1.07E-01	15	7.13E-03
Monochloroacetic acid	1.64E-02	85	1.93E-04	2.83E-02	85	3.33E-04	2.15E-03	85	2.53E-05
Dichloroacetic acid	5.21E-04	23	2.27E-05	5.21E-04	23	2.27E-05	1.38E-02	23	6.00E-04
Trichloroacetic acid	2.69E-04	100	2.69E-06	2.69E-04	100	2.69E-06	2.80E-02	100	2.80E-04
Monobromoacetic acid	2.69E-04	1.4	1.92E-04	2.69E-04	1.4	1.92E-04	9.67E-03	1.4	6.91E-03
Dibromoacetic acid	2.69E-04	69	3.90E-06	8.24E-01	69	1.19E-02	3.26E-02	69	4.72E-04
Tribromoacetic acid	8.97E-02	69	1.30E-03	1.41E-01	69	2.04E-03	7.86E-02	69	1.14E-03
Bromochloroacetic acid	4.28E-02	69	6.20E-04	4.28E-02	69	6.20E-04	1.17E-01	69	1.70E-03
Dibromochloroacetic acid	2.69E-04	55.6	4.84E-06	7.25E-01	55.6	1.30E-02	5.52E-02	55.6	9.93E-04
Dichlorobromoacetic acid	8.08E-04	63.8	1.27E-05	2.77E-02	63.8	4.34E-04	2.02E-02	63.8	3.17E-04
Chloropicrin	1.62E-03	2.2	7.36E-04	5.20E-02	2.2	2.36E-02	2.83E-02	2.2	1.29E-02
Monobromoacetonitrile	6.34E-01	0.55	1.15E+00	1.19E-01	0.55	2.16E-01	2.02E-02	0.55	3.67E-02
Dibromoacetonitrile	1.81E+01	0.55	3.29E+01	1.55E+00	0.55	2.82E+00	1.98E-01	0.55	3.60E-01
2,4,6-Tribromophenol	8.07E-03	1	8.07E-03	8.07E-03	1	8.07E-03	8.07E-03	1	8.07E-03
1,2,3-Trichloropropane	7.55E-03	8.8	8.58E-04	7.55E-03	8.8	8.58E-04	7.55E-03	8.8	8.58E-04

Risk assessment of the aquatic environment due to chemicals in ballast water was carried out by calculating PEC/PNEC ratios. If the PEC/PNEC ratio is less than or equal to 1, the chemical is not regarded as an immediate concern. If the PEC/PNEC ratio is greater than 1, the substance should be treated as a hazardous one.

The PEC/PNEC ratio calculated for each chemical is mostly far less than 1 even under the worst-case scenario, except for monobromacetonitrile in seawater and dibromoacetonitrile in seawater and brackish water. Overall, the chemical analyses (tables 3.3 and 3.4) and the toxicity tests (Tables 6.3 and 6.4) show that there is negligible risk to the aquatic environment. Neither potentially hazardous substances nor significant acute toxicity in the treated water samples were observed for the BlueZone™ BWMS evaluated in this report.

Under worst-case emission scenarios, discharged water will be diluted at a minimum dozens of times or more, so any residual toxicity would seem to be insignificant both during and after deballasting if actual conditions are similar to the test conditions in this report.

8 ASSESSMENT REPORT (G9: 4.3)

The constituents associated with the BlueZone™ BWMS were evaluated for a variety of endpoints, including toxicity, bioaccumulation and persistence in the environment. The physical and chemical properties were evaluated to assess the proper chemical handling and/or storage and risks related to fire and explosion. Treated ballast water discharge and risks of the COCs to human health were also evaluated. As the Active Substance is generated on board as required and neutralized prior to discharge, it is the treated ballast water and DBPs potentially present that are the most important to consider for this evaluation.

During the land-based test runs of the BlueZone™ BWMS meeting ballast water performance standard concerning biological efficacy, the amounts of Active Substance and Relevant Chemicals were measured and the acute and chronic WET tests using representative marine and freshwater species of algae, rotifer as invertebrates and fish were conducted for treated seawater (33 PSU), brackish water (21 PSU) and fresh water (< 3 PSU).

The human health risk assessment data showed that the BlueZone™ BWMS poses negligible risk on both ship crew conducting ballast water sampling and cleaning and general public swimming and consuming fish near the discharging point.

The PEC in GESAMP Model Harbour was predicted by using the modelling of MAMPEC-BW Model 3.0 and the PNEC was determined from the selected aquatic toxicity data and assessment factors. Overall, the PEC/PNEC ratios for Relevant Chemicals were far less than 1, but a little over 1 for monobromacetonitrile in seawater and dibromoacetonitrile in seawater and brackish water. However, ecological risks posed by the BlueZone™ BWMS are negligible, even when the PECs were modelled based on the maximum concentration for all saline, brackish, and fresh water.

The BlueZone™ BWMS is not likely to cause health risks for humans and the aquatic environment.

9 APPENDICES CONTAINED IN THE CONFIDENTIAL DOSSIER

APPENDIX I	KEY DATA SUMMARY
APPENDIX II	QAPP FOR BIOLOGICAL EFFICACY TEST AND TEST REPORT
APPENDIX III	QAPP FOR CHEMICAL ANALYSIS AND TEST REPORTS
APPENDIX IV	QAPP FOR AQUATIC TOXICITY TEST AND TEST REPORTS
APPENDIX V	REFERENCE ECOTOXICITY DATA FROM LITERATURES
APPENDIX VI	HUMAN RISK ASSESSMENT OF BALLAST WATER CHEMICALS
APPENDIX VII	PEC USING MAMPEC BW 3.0 MODEL
APPENDIX VIII	SYSTEM DESCRIPTION OF THE BLUEZONE™ BWMS
APPENDIX IX	THE RESULTS OF TRO MONITORING
APPENDIX X	MATERIAL SAFETY DATA SHEET
APPENDIX XI	CORROSION STUDY
APPENDIX XII	OPERATION AND SAFETY MANUALS
APPENDIX XIII	LOGGED DATA FROM TEST CYCLES
APPENDIX XIV	SYSTEM DRAWINGS
APPENDIX XV	COMPONENT MANUALS
APPENDIX XVI	GAS DETECTION REPORT
APPENDIX XVII	REFERENCES